(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 October 2003 (02.10.2003)

PCT

(10) International Publication Number
WO 03/080366 A2

(51) International Patent Classification⁷: B60B

(21) International Application Number: PCT/US03/08267

(22) International Filing Date: 19 March 2003 (19.03.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/365,618 20 March 2002 (20.03.2002) US
10/101,188 20 March 2002 (20.03.2002) US

(71) Applicant *(for all designated States except US)*: **DANA CORPORATION** [US/US]; P.O. Box 904, Toledo, OH 43697 (US).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **ALLMANDINGER, Timothy, B.** [US/US]; 2917 East 1100 North, Roanoke, IN 46783 (US). **HOEFER, Sean, K.** [US/US]; 657 Fery Street, Wabash, IN 46992 (US). **MASER, Gregory, J.** [US/US]; 9622 Carine Cove, Ft. Wayne, IN 46835 (US). **NANUA, Parvinder, S.** [US/US]; 10622 Mohave Court, Ft. Wayne, IN 46804 (US). **STUART, Edward, E.** [US/US]; 4750 Flat Rock Trail, Payne, OH 45880 (US). **IRWIN, Earl, J.** [US/US]; 12409 Burning Tree Road, Ft. Wayne, IN 46845 (US).

(74) Agents: **STAVISH, Matthew, W.** et al.; LINIAK, BERENATO & WHITE, 6550 Rock Spring Drive, Suite 240, Bethesda, MD 20817 (US).

(81) **Designated States** *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) **Designated States** *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 03/080366 A2

(54) Title: MODULAR DRIVE AXLE ASSEMBLY FOR MOTOR VEHICLES

(57) Abstract: A drive axle assembly for motor vehicles, includes a support beam member having a substantially flat, enlarged central section and two opposite arm sections axially outwardly extending from the central section, a differential carrier unit secured to the flat central section of the support beam member, and two opposite axle shaft members outwardly extending from the carrier unit and rotatably supported by the arm sections in a spaced relationship with respect to the central section of the support beam member. The differential carrier unit includes a carrier frame member fastened to the central section of the support beam member, and provided for rotatably supporting a differential case and a drive pinion. The differential carrier unit is enclosed into a housing formed by rear and front covers secured to oposite surfaces of the central section of the support beam member. The rear cover incorporates two throughholes provided with self-centering seals.

MODULAR DRIVE AXLE ASSEMBLY FOR MOTOR VEHICLES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to drive axle assemblies for motor vehicles in general, and more particularly to a modular drive axle assembly, for both rigid and independent axle designs, including a support member having a substantially flat central section, a differential carrier unit fastened to the support member, and two opposite left and right shafts rotatably supported by the differential carrier unit in a spaced relationship with respect to the flat central section of the support member in a driving direction of the motor vehicle.

2. Description of the Prior Art

Rigid drive axle assemblies are well known structures that are in common use in most motor vehicles. Such axle assemblies include a number of components that are adapted to transmit rotational power from an engine of the motor vehicle to wheels thereof. Typically, the rigid drive axle assembly includes a hollow axle housing, a differential, which is rotatably supported within the axle housing by a non-rotating carrier. The differential is connected between an input drive shaft extending from the vehicle engine and a pair of output axle shafts extending to the vehicle wheels. The axle shafts are contained in respective non-rotating tubes that are secured to the carrier. Thus, rotation of the differential by the drive shaft causes

corresponding rotation of the axle shafts. The carrier and the tubes form a housing for these drive train components of the axle assembly, inasmuch as the differential and the axle shafts are supported for rotation therein.

The axle housings are generally classified into two basic types. The first axle housing type is a unitized carrier construction, commonly referred to as a Salisbury or Spicer type axle assembly, illustrated in Fig. 1. In this structure, the Salisbury type axle assembly 301 includes a carrier 312 (which houses the rotatable differential mechanism 340) is directly connected to the two tubes 316 and 317 (which house the rotatable axle shafts 320). An opening is provided at the rear of the carrier to permit assembly of the differential therein. A cover 326 closes this opening during the use. The cover 326 is connected by bolts 328 to a rear face 330 of the carrier 312 hydraulically seals the housing against the passage of lubricant. A brake assembly 314 located at the end of a tube 316 extending outboard from the ends of an axle carrier 312. Located within the differential case is a drive pinion 332 rotatably supported by a rear drive pinion bearing 334 and a front drive pinion bearing (not shown) supported on the inner surface of a portion of the axle carrier casing 338 that extends forward from the center line of the axle assembly. A driveshaft, driveably connected to the output shaft of a transmission, is coupled to the shaft of the drive pinion 332. The differential mechanism 340, located within the differential case 348, includes a ring gear 342, in continuous meshing engagement with drive pinion 332 and supported rotatably on the differential rear drive pinion bearing 334 and the front drive pinion bearing located within the housing gear and cylindrical extension 338 of the carrier 312. The axle carrier 312 also includes laterally directed tubular extensions 344, 346, which receive therein the ends of housing tubes 316 and 317,

respectively. Located within the carrier 312 is a differential case 348, on which bevel pinion gears 350, 352 are supported for rotation on a differential pinion shaft 354. Side bevel gears 356, 358 are in continuous meshing engagement with pinions 350, 352 and are driveably connected to left and right axle shafts 320, located respectively within tubes 316 and 317. The axle shaft 320 is connected to the corresponding side bevel gear 356. Unitized carrier axle housing constructions of this type are economical to manufacture and are readily adaptable for a variety of vehicles.

The second axle housing type is a separable carrier construction, and is commonly referred to as a Banjo type axle, illustrated in Fig. 2. In this structure, the Banjo type axle 401includes an axle housing 402 having axle tubes 406a and 406b connected together by a central member 404. The axle tubes 406a and 406b are adapted to receive and rotatably support output axle shafts 414a and 414b. The axle housing 402 is formed separate and apart from a carrier 422. This central member 404 is generally hollow and cylindrical in shape, having a large generally circular opening 410 formed therethrough. During assembly, a differential 420 is first assembled within the carrier 422, then the carrier 422 is secured to the central member 404 of the axle housing 402. The overall shape of this type of axle housing (i.e., the generally round shape of the central member 404 and the elongated tubes 406a and 406b extending therefrom) generally resembles the shape of a banjo musical instrument. Hence, this type of axle housing is referred to as the Banjo type axle housing. The Banjo type axle housings are advantageous because the carrier 422 and differential 420 can be removed from the axle assembly 401 for service without disturbing the other components thereof.

However, both Banjo and Salisbury type axles have their disadvantages. Thus, there is

a need for a rigid drive axle assembly that combines the advantages of both Banjo and Salisbury type axles and lessens their shortcomings.

Independent drive axle assemblies are also known structures that are in use in many motor vehicles and are adapted to transmit rotational power from an engine of the motor vehicle to wheels thereof. The independent drive axles typical have differential gear assemblies directly mounted to a frame or body structure of the motor vehicle, such that they do not travel in relation to the wheel travel. As illustrated in Fig. 3, the conventional independent drive axle of the motor vehicle includes a differential carrier 500 housing a final drive and a differential mechanism. The differential carrier 500 is mounted to a vehicle frame including two side members 502 as well as two cross members, specifically a cross member 503 which is in the front in the forward driving direction and a rearward cross member 504. The forward driving direction of the vehicle to whose body the member frame, in particular, is elastically linked, is indicated in the Fig. 3 by an arrow F. A drive propeller shaft leads into the differential carrier 500 on the side of the forward cross member 503. In the rearward area of this differential carrier 500, drive shafts 505 for drivable wheels of the vehicle (not shown) are coupled. These wheels are coupled between the cross members 503 and 504 to the side members 502 in a manner not shown in the drawing.

The suspension of the differential carrier 500 takes place elastically on both cross members 503 and 504. A lever is provided for the bearing arrangement of the differential carrier 500 situated in the front in the driving direction. The lever is constructed there as a U-shaped lever 510, the free legs of the U reaching around the differential carrier 500 and being swivelably connected on their respective ends with the differential carrier 500 through

bearings 509. The lever 510 is attached to the forward cross member 503 through elastic bearings 508. A rear end of the differential carrier 500 is attached to the rearward cross member 504 through an elastic bearing 512.

However, conventional independent drive axles have their disadvantages. As the differential carrier is attached directly to the vehicle frame or the vehicle underbody, it should be strong enough to carry various loads from the vehicle drive train and the road surface. Thus, typical differential carriers for the independent drive axles have relatively low strength to weight ratio, they use costly metal alloys, expensive in manufacturing, and are laborious in assembling/disassembling and servicing of the axle assembly.

Thus, there is a need for an independent drive axle assembly that overcomes shortcomings of the conventional independent drive axles.

SUMMARY OF THE INVENTION

The present invention provides a novel modular drive axle assembly for motor vehicles for both rigid and independent axle designs and may be used for both front and rear axle applications. The modular drive axle assembly in accordance with the present invention comprises a support member having a substantially flat central section, a differential carrier unit fastened to the support member, and two opposite left and right shafts rotatably supported by the differential carrier unit in a spaced relationship with respect to the flat central section of the support member in a driving direction of the motor vehicle.

In accordance with the first invention, the modular drive axle assembly is a rigid drive axle assembly. The rigid drive axle assembly in accordance with the first invention comprises the support member in the form of a support beam member having a substantially flat, enlarged central section and two opposite arm sections axially outwardly extending from the central section. The rigid drive axle assembly further comprises the differential carrier unit fastened to the enlarged central section of the support beam member, and two opposite axle shaft members outwardly extending from the differential carrier unit, and rotatably supported by the arm sections of the support beam member so that the axle shaft members are spaced from the central section of the support beam member in a driving direction of the motor vehicle. Distal ends of the axle shaft members are provided with flange members adapted for mounting corresponding wheel hubs.

The differential carrier unit includes a carrier frame member fastened to the central section of the support beam member, and provided for rotatably supporting a differential case and a drive pinion. The differential case houses a conventional differential gear mechanism, well known to those skilled in the art. The drive pinion has a pinion gear in continuous meshing engagement with a ring gear, and a pinion shaft operatively coupled to a vehicular drive shaft driven by a vehicular powerplant through an input yoke. The differential carrier unit is enclosed into a housing formed by a rear cover and a front cover secured to opposite surfaces of the central section of the beam member in any appropriate manner well known in the art. The front cover has a font opening for rotatably supporting and receiving therethrough a distal end of the pinion shaft of the drive pinion. The rear cover incorporates two opposite through holes for receiving the axle shaft members therethrough. Each of the through holes is

provided with a self-centering seal.

The carrier frame member is, preferably, a single-piece metal part manufactured by casting or forging. The differential carrier frame member has a generally Y-shaped configuration and includes a neck portion and two opposite, axially spaced, coaxial bearing hub portions attached to the neck portion through respective leg portions. The neck portion has an opening therethrough adapted for receiving and rotatably supporting the drive pinion through an appropriate anti-friction bearing, preferably a roller bearing. The bearing hub portions are provided with respective openings therethrough adapted for receiving appropriate anti-friction bearings for rotatably supporting the differential case. Moreover, the bearing hub portions are provided with mounting flange portions.

Further in accordance with the first exemplary embodiment of the first invention, the support beam member has the substantially flat, enlarged central section and the two opposite, substantially rectangular arm sections axially outwardly extending from the central section. Preferably, the support beam member is formed of a single-piece C-channel body manufactured by a metal deforming, such as stamping, having a substantially flat, enlarged central section and two opposite arm sections axially outwardly extending from the central section. The flat enlarged central section is further provided with a central opening therethrough adapted for receiving the differential carrier frame member of the differential carrier unit. The support beam member further includes two structural plates attached to the arm sections so as to form the tubular arm sections of substantially rectangular cross-section.

In accordance with the second exemplary embodiment of the first invention, the support beam member has the substantially flat, enlarged central section and the two opposite,

substantially tubular arm sections axially outwardly extending from the central section. Preferably, the support beam member is formed of a single-piece C-channel body manufactured by a metal deforming, such as stamping, having a substantially flat, enlarged central section and two opposite arm sections axially outwardly extending from the central section. The flat enlarged central section is further provided with a central opening therethrough adapted for receiving the differential carrier frame member of the differential carrier unit. The arm sections of the single-piece C-channel body are deformed so as to form the substantially tubular arm sections of the support beam member.

The preferred embodiment of a method of manufacturing the support beam member in accordance with the second exemplary embodiment of the first invention includes the steps of forming a blank cut out of a sheet of metal, drawing of the blank, trimming ends of the blank to eliminate any deformation that has occurred during the drawing, re-striking and pre-curling to start shaping the central section of the support beam member, curling the tubular arm sections, finishing the tubular arm sections and creating the required diameter of the tubular arm sections of the support beam member, cam re-striking to reinforce the integrity of the support beam member and final form of flange edges, piercing the central opening adapted to receive the carrier frame member, and piercing and extruding bolt holes for mounting the carrier frame member and holes for mounting the rear cover and the front cover.

In accordance with the third exemplary embodiment of the first invention, the support beam member has a substantially flat, enlarged central section and two opposite substantially flat arm sections axially outwardly extending from the central section. Preferably, in this embodiment, the support beam member is formed of a substantially flat integral profiled

body. Preferably, the body is a substantially flat, I-shaped metal profile.

The body has an enlarged central section and two opposite arm sections axially outwardly extending from the central section. The enlarged central section of the body defines the central section of the support beam member. The enlarged central section is further provided with a central opening therethrough adapted for receiving the differential carrier frame member. Fixed at distal ends of the arm sections of the support beam member are corresponding shaft supporting brackets. Each of the shaft supporting brackets has a hole therethrough adapted to receive and rotatably support the axle shaft members in a spaced relationship with respect to the body of the support beam member.

Therefore, the axle assembly in accordance with the first invention represents a novel arrangement of the rigid drive axle assembly providing a number of advantages over the currently employed Salisbury and Banjo style axles, such as improved strength to weight ratio, ease of manufacturing and reduced manufacturing cost due to the use of simple metal stampings to produce the support beam member and the front cover, ease of assembly/disassembly and servicing of the axle assembly, and improved modularity and commonality of axle components.

In accordance with the second invention, the modular drive axle assembly is an independent drive axle assembly that may be used for both front and rear axle applications. The independent drive axle assembly in accordance with the preferred embodiment of the second invention comprises a support plate member having a substantially flat central section, a differential carrier unit fastened to the central section of the support plate member, and two opposite stub shaft members outwardly extending from the differential carrier unit so that the

stub shaft members are spaced from the central section of the support plate member in a driving direction of the motor vehicle. Distal ends of the stub shaft members are provided with flange members adapted for mounting corresponding axle shafts, preferably via universal joints.

The vehicular independent drive axle assembly of the second invention is adapted to be elastically mounted to a sprung mass of the motor vehicle, such as a frame or a vehicle underbody. For this purpose, the independent drive axle assembly is provided with at least one, preferably two mounting members formed integrally with the central section of the support plate member, and at least one front suspension member provided at a front portion of the differential carrier unit for further securing the independent drive axle assembly to the sprung mass of the motor vehicle.

The differential carrier unit includes a carrier frame member fastened to the central section of the support beam member, and provided for rotatably supporting a differential case and a drive pinion. The differential case houses a conventional differential gear mechanism, well known to those skilled in the art. The drive pinion has a pinion gear in continuous meshing engagement with a ring gear, and a pinion shaft operatively coupled to a vehicular drive shaft driven by a vehicular powerplant through an input yoke. The differential carrier unit is enclosed into a housing formed by a rear cover and a front cover secured to opposite surfaces of the central section of the beam member in any appropriate manner well known in the art. The front cover has a front opening for rotatably supporting and receiving therethrough a distal end of the pinion shaft of the drive pinion. The rear cover incorporates two opposite through holes for receiving the axle shaft members therethrough. Each of the

through holes is provided with a self-centering seal.

The differential carrier frame member is, preferably, a unitary, single-piece metal part manufactured by casting or forging. The differential carrier frame member has a generally Y-shaped configuration and includes a neck portion and two opposite, axially spaced, coaxial bearing hub portions attached to the neck portion through respective leg portions. The neck portion has an opening therethrough adapted for receiving and rotatably supporting the drive pinion through an appropriate anti-friction bearing, preferably a roller bearing. The bearing hub portions are provided with respective openings therethrough adapted for receiving appropriate anti-friction bearings for rotatably supporting the differential carrier. Moreover, the bearing hub portions are provided with mounting flange portions.

Therefore, the independent drive axle assembly in accordance with the second invention represents a novel arrangement of the independent drive axle assembly providing a number of advantages over the currently employed independent drive axles, such as improved strength to weight ratio, ease of manufacturing and reduced manufacturing cost due to the use of simple metal stampings to produce the support beam member and the front cover, ease of assembly/disassembly and servicing of the axle assembly, and improved modularity and commonality of axle components.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent from a study of the following specification when viewed in light of the accompanying drawings, wherein:

Fig. 1 is an exploded perspective view of a typical Salisbury type drive axle assembly of the prior art;

Fig. 2 is an exploded perspective view of a typical Banjo type drive axle assembly of the prior art;

Fig. 3 is a perspective view of a typical independent drive axle assembly of the prior art;

Fig. 4 is a perspective view from the rear of an axle assembly in accordance with the first embodiment of the first invention;

Fig. 5 is an exploded perspective view from the rear of the axle assembly in accordance with the first embodiment the first invention;

Fig. 6 is a partial exploded perspective view from the front of the axle assembly in accordance with the first embodiment the first invention;

Fig. 7 is a perspective view of a support beam member of the axle assembly in accordance with the first exemplary embodiment of the first invention;

Fig. 8 is perspective view of a differential carrier frame member in accordance with the present invention;

Fig. 9 is a perspective view of a support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 10 illustrates a first step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 11 illustrates a second step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 12 illustrates a third step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 13 illustrates a fourth step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 14 illustrates a fifth step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 15 illustrates a sixth step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 16 illustrates a seventh step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 17 illustrates a eighth step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 18 illustrates a ninth step of manufacturing of the support beam member of the axle assembly in accordance with the second exemplary embodiment of the first invention;

Fig. 19 is a partial exploded perspective view from the rear of an axle assembly in accordance with the third exemplary embodiment of the first invention;

Fig. 20 is a perspective view from the rear of the axle assembly in accordance with the third exemplary embodiment of the first invention;

Fig. 21 is a perspective rear view of an independent drive axle assembly in accordance with the second invention in an assembled condition;

Fig. 22 is a perspective front view of an independent drive axle assembly in accordance with the second invention in an assembled condition;

Fig. 23 is a perspective front view of an independent drive axle assembly in accordance with the second invention in an assembled condition with removed front cover;

Fig. 24 is an exploded perspective view of the axle assembly in accordance with the second invention;

Fig. 25 is an exploded perspective view of the axle assembly in accordance with the second invention;

Fig. 26 is a partial exploded perspective view from the front of the axle assembly in accordance with the second invention;

Fig. 27 is a perspective view of a support plate member of the axle assembly in accordance with the second invention;

Fig. 28 is perspective view of a differential carrier unit in accordance with the second invention;

Fig. 29 is perspective view of a differential carrier frame member in accordance with the second invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will now be described with the reference to accompanying drawings. As used herein, the words "front" and "rear" in the following description are referred with respect to a driving direction of a motor vehicle, as indicated in the accompanying drawing figures by an arrow F.

Figs. 4-20 illustrate a modular drive axle assembly in accordance with the first

invention. The modular drive axle assembly of the first invention is a rigid drive axle assembly.

Figs. 4-8 depict a vehicle drive axle assembly 1 in accordance with the first exemplary embodiment of the first invention. The drive axle assembly 1 comprises a support beam member 2 having a substantially flat, enlarged central section 4 and two opposite, substantially tubular arm sections 6a and 6b axially outwardly extending from the central section 4. The flat central section 4 of the support beam member 2 defines a support plane that is substantially orthogonal to the driving direction F of the motor vehicle.

The drive axle assembly 1 further comprises a differential carrier unit 20 fastened to the enlarged central section 4 of the support beam member 2, and two opposite axle shaft members 14a and 14b outwardly extending from the differential carrier unit 20, and rotatably supported by the arm sections 6a and 6b of the support beam member 2 so that the axle shaft members 14a and 14b are spaced from the central section 4 of the beam member 2 in the driving direction F of the motor vehicle. Distal ends of the axle shaft members 14a and 14b are provided with flange members 15a and 15b, respectively, adapted for mounting corresponding wheel hubs 17a and 17b.

The differential carrier unit 20 includes a carrier frame member 22 fastened to the central section 4 of the beam member 2, and provided for rotatably supporting a differential case 34 and a drive pinion 38. The differential case 34 houses a conventional differential gear mechanism, well known to those skilled in the art. The drive pinion 38 has a pinion gear 38a in continuous meshing engagement with a ring gear 36, and a pinion shaft 38b operatively coupled to a vehicular drive shaft (not shown) driven by a vehicular powerplant (not shown),

such as an internal combustion engine, through an input yoke 39. The ring gear 36 is conventionally secured to the differential case 34 in any appropriate manner well known in the art.

Therefore, the differential carrier unit 20 of the present invention is a self-contained unit wherein the carrier frame member 22 supports all the significant elements of the differential carrier unit and a final drive, such as the differential case 34 housing the differential gear mechanism, differential bearings 35a and 35b, threaded differential adjusters 32a and 32b, differential adjuster locks, oil seals, the drive pinion 38, drive pinion bearings, and the input yoke 39. Preferably, the carrier frame member 22 fastened to the central section 4 of the support beam member 2 using conventional fasteners, such as bolts 21. The carrier frame member 22 of the present invention improves the modularity of design of the differential carrier unit, substantially simplifies the assembly and servicing of the differential carrier unit, and reduces the number of required machining operations.

In order to prevent the differential carrier unit 20 from contamination and provide a supply of a lubricant, the differential carrier unit 20 is enclosed into a housing formed by a rear cover 40 and a front cover 46 secured to opposite surfaces of the central section 4 of the beam member 2 in any appropriate manner well known in the art. In accordance with the preferred embodiment of the present invention, both the rear cover 40 and the front cover 46 are manufactured by metal stamping of any appropriate metal material, such as steel. Preferably, the front cover 46 is welded to a front surface of the central section 4 of the beam member 2, while the rear cover 40 is fastened to a rear surface of the central section 4 of the beam member 2 using conventional fasteners. The front cover 46 has a front opening 48

(shown in Fig. 5) for rotatably supporting and receiving therethrough a distal end of the pinion shaft 38b of the drive pinion 38. The rear cover 40 incorporates two opposite through holes 42 (only one is shown in Fig. 5) for receiving the axle shaft members 14a and 14b therethrough. Each of the through holes 42 is provided with a self-centering seal 44.

The opposite arm sections 6a and 6b of the support beam member 2 may be provided with spring seats 48a and 48b, respectively.

Fig. 7 depicts in detail the support beam member 2 in accordance with the first exemplary embodiment of the first invention. As was explained above, the support beam member 2 has the substantially flat, enlarged central section 4 and the two opposite, substantially tubular arm sections 6a and 6b axially outwardly extending from the central section 4. Preferably, in this embodiment, the support beam member 2 is formed of a single-piece C-channel body 8 manufactured by a metal deforming, such as stamping, having a substantially flat, enlarged central section 8c and two opposite arm sections 8a and 8b axially outwardly extending from the central section 8c.

The substantially flat, enlarged central section 8c of the body 8 defines the central section 4 of the support beam member 2. The flat enlarged central section 8c is further provided with a central opening 10 therethrough adapted for receiving the carrier frame member 22 of the differential carrier unit 20. A plurality of bolt holes 9 are formed in the central section 8c adjacent to the central opening 10 and adapted to receive the bolts 21 for fastening the carrier frame member 22 to the flat central section 4 of the support beam member 2.

The support beam member 2 further includes two structural plates 12a and 12b

attached to the arm sections 8a and 8b, respectively, in any appropriate manner, such as welding, so as to form the substantially tubular arm sections 6a and 6b of the support beam member 2 housing the axle shaft members 14a and 14b. As shown in Fig. 6, the tubular arm sections 6a and 6b of the support beam member 2 have substantially rectangular cross-section. Inward ends of each of the structural plates 12a and 12b is provided with a notch 16 receiving the axle shaft member 14a or 14b therethrough in a spaced relationship with respect to the central section 8c of the body 8 of the support beam member 2.

The carrier frame member 22, illustrated in detail in Fig. 8, is, preferably, a single-piece metal part manufactured by casting, such as ductile iron casting. It will be appreciated by those skilled in the art that any appropriate metal or non-metal material or method of manufacturing may be utilized for producing the carrier frame member 22 of the present invention, such as aluminum casting, steel stamping, forging, etc.

The carrier frame member 22 has a generally Y-shaped configuration and includes a neck portion 24 and two opposite, axially spaced, coaxial bearing hub portions 26a and 26b attached to the neck portion 24 through respective leg portions 28a and 28b. The neck portion has an opening 25 therethrough adapted for receiving and rotatably supporting the drive pinion 38 through an appropriate anti-friction bearing (not shown), preferably a tapered roller bearing. The bearing hub portions 26a and 26b are provided with respective openings 27a and 27b therethrough adapted for receiving appropriate anti-friction bearings 35a and 35b for rotatably supporting the differential case 34. Preferably, the anti-friction bearings 35a and 35b are tapered roller bearings. Moreover, the bearing hub portions 26a and 26b are provided with mounting flange portions 30a and 30b respectively, for fastening the carrier frame member 22

to the flat central section 4 of the support beam member 2. Preferably, each of the mounting flange portions 30a and 30b has two mounting holes 31a and 31b, respectively, adapted to receive the bolts. In an assembled condition of the drive axle assembly 1, the bolts 21 extend through the mounting holes 31a and 31b in the carrier frame member 22 and the bolt holes 9 formed in the central section 8c of the body 8 to extend through the support beam member 2, thus fastening the carrier frame member 22 to the central section 4 of the beam member 2.

Fig. 9 of the drawings depicts a second exemplary embodiment of a drive axle assembly of the first invention. The drive axle assembly of the second exemplary embodiment of the present invention corresponds substantially to the drive axle assembly of the first exemplary embodiment shown in Figs. 4-8, and only the support beam member of the axle assembly, which differs, will therefore be explained in detail below. To simplify the description, all elements of the second exemplary embodiment of the first invention similar to those of the first exemplary embodiment are designated by numerals 100 higher. The parts in common with Figs. 4-8 are designated by the same reference numeral.

Fig. 9 depicts in detail a support beam member 102 in accordance with the second exemplary embodiment of the first invention. To simplify the description, all elements of the second exemplary embodiment of the first invention similar to those of the first exemplary embodiment are designated by numerals 100 higher. The parts in common with Figs. 4-8 are designated by the same reference numeral.

As was explained above, the support beam member 102 has a substantially flat, enlarged central section 104 and two opposite arm sections 106a and 106b axially outwardly extending from the central section 104. Preferably, in this embodiment, the support beam

member 102 is formed of a single-piece C-channel body 108 manufactured by a metal deforming, such as stamping, having a substantially flat, enlarged central section 108c and two opposite arm sections 108a and 108b axially outwardly extending from the central section 108c.

The substantially flat, enlarged central section 108c of the body 108 defines the central section 104 of the support beam member 102. The flat enlarged central section 108c is further provided with a central opening 110 therethrough adapted for receiving the differential carrier frame member 22 of the differential carrier unit 20 (not shown in Fig. 9) and triangular-shaped holes 112. A plurality of bolt holes 109 are formed in the central section 108c adjacent to the central opening 110 and adapted to receive the bolts for fastening the carrier frame member 22 to the flat central section 104 of the support beam member 102.

The arm sections 108a and 108b of the C-channel body 108 are plastically deformed to form a substantially tubular arm sections 106a and 106b with seam welds 116 along a neutral axis of the thereof. The tubular arm sections 106a and 106b of the support beam member 102 houses the axle shaft members 14a and 14b (not shown in Fig. 8) in a spaced relationship with respect to the flat central section 108c of the body 108 of the support beam member 102. Those of ordinary skill in the art will appreciate that arm sections 106a and 106b may have many other shapes that could be used for the same purpose, such as elliptical. Thus, the support beam member 102 is formed of a single-piece C-channel body 108.

The preferred embodiment of a method of manufacturing the support beam member 102 in accordance with the second exemplary embodiment of the first invention is illustrated in Figs. 10-18 and performed in the following manner.

The first step is the operation of forming a blank 2 cut out of a sheet of metal 150. As illustrated in Fig. 10, a number of substantially identical blanks 152 is cut out of the metal sheet 1 by any appropriate method known in the art, such as by a single punching operation. Preferably, this operation occurs in a separate cutting die (not shown) from a forming die (not shown), using a first press apparatus, such as a 1000T press (not shown). The tool cuts a basic shape of the axle housing when it is in a flat state, before it is formed. This creates the blank 152. Piercing occurs at the same time. Punches and die buttons are used to pierce holes 154 and 156 in the blank 152. These holes will be used to retain and locate the blank 152 in the second forming die. The elliptical holes 156 are pre-pierced for the triangular-shaped holes 112 in the support beam member 102 that will be located in this area. These holes 156 will allow metal stretch for forming. The flat blanks 152 are stacked in lots for transfer to the forming die in another press.

The second step is the operation of drawing of the blank 152, illustrated in Fig. 11. This operation and all of the following operations are done in a second press apparatus, such as a 2000T press. All of the following operations occur simultaneously in a single tandem die. The intention of the draw operation at this step is to start to form the metal towards a desired end form. It will create flow in the metal so that the final stages of the manufacturing operation can be performed. It is a pre-form. This is created by using an upper form (die) and a lower form (die).

The third step is the operation of trimming ends and piercing, illustrated in Fig. 12. In this operation, end portions 158 of the blank 152 are trimmed to eliminate any deformation that has occurred during the draw or pre-form operation in the step two. At the same time the

triangular lightening holes 156 can now be pierced. Upper punches and lower die steels (not shown) are used to accomplish this.

The fourth step is the operation of re-striking and pre-curling, illustrated in Fig. 13. In this operation, the blank 152 is deformed to start shaping the central section of the support beam member 102, and side flanges 160 along the end portions 158 of the blank 152 are formed. The longitudinal edges of the blank 152 are formed so as to reflect the required diameter of the tubular arm sections 106a and 106b of the support beam member 102. This will use six upper and lower form dies.

The fifth step is the operation of curling the tubular arm sections, illustrated in Fig. 14. In this operation, the blank 152 is deformed to form the central section 104 and the tubular arm sections 106a and 106b of the required diameter of the support beam member 102. This operation requires two upper form dies and two lower form dies. It also requires center upper and lower spacer dies that will be used to locate and retain the support beam member while the tubular arm sections are formed.

The sixth step is the operation of finishing the tubular arm sections, illustrated in Fig. 15. In this operation, the upper form and lower form wrap entirely around to create the required diameter of the tubular arm sections 106a and 106b of the support beam member 102. This operation will require two upper form dies and two lower form dies. It will also require center upper and lower spacer dies that will be used to locate and retain the support beam member while the tubular arm sections are formed.

The seventh step is the operation of cam re-striking, illustrated in Fig. 16. In this operation, re-strike is used to reinforce the integrity of the support beam member and final

form of flange edges. The cam will trim the formed edges of the material for uniformity. This operation will require two upper form dies and two lower form dies. Approximately four cams will be required.

The eighth step is the operation of piercing, illustrated in Fig. 17. In this operation, central opening 110 adapted to receive the carrier frame member 22 is cut away. This requires one upper punch and one lower die section as well as supporting blocks for the tubular arm sections.

The ninth step is the operation of piercing and extruding, illustrated in Fig. 18. In this operation, the bolt holes 109 for mounting the carrier frame member 22, and holes for mounting the rear cover 40 and the front cover 46 are pierced. The triangular shaped lightening holes 112 are extruded to create part rigidity. Upper punches and lower die buttons are required for the round holes. Two upper extrusion punches and two lower die steels are required for the extrusion of the rectangular lightening holes.

Figs. 19 and 20 of the drawings depict a third exemplary embodiment of a drive axle assembly of the first invention. The drive axle assembly of the third exemplary embodiment of the first invention corresponds substantially to the drive axle assembly of the first exemplary embodiment shown in Figs. 4-8, and only the support beam member of the axle assembly, which differs, will therefore be explained in detail below. To simplify the description, all elements of the third exemplary embodiment of the first invention similar to those of the first exemplary embodiment are designated by numerals 200 higher. The parts in common with Figs. 4-8 are designated by the same reference numeral.

Fig. 19 depicts in detail a support beam member 202 in accordance with the third

exemplary embodiment of the present invention. As was explained above, the support beam member 202 has a substantially flat, enlarged central section 204 and two opposite substantially flat arm sections 206a and 206b axially outwardly extending from the central section 204. Preferably, in this embodiment, the support beam member 202 is formed of a substantially flat integral profiled body 208. Preferably, the body 208 is a substantially flat, I-shaped metal profile that could be a single-piece part, or, alternatively, made of two C-channel metal profiles welded together. Those of ordinary skill in the art will appreciate that there are many various profiles that could be used for the same purpose.

The body 208 has an enlarged central section 208c and two opposite arm sections 208a and 208b axially outwardly extending from the central section 208c. The enlarged central section 208c of the body 208 defines the central section 204 of the support beam member 202. The enlarged central section 208c is further provided with a central opening 210 therethrough adapted for receiving the carrier frame member 22. A plurality of bolt holes 209 are formed in the central section 208c adjacent to the central opening 210 and adapted to receive the bolts for fastening the carrier frame member 22 to the support beam member 202.

As illustrated in Figs. 19 and 20, fixed at distal ends of the arm sections 206a and 206b of the support beam member 202 are corresponding shaft supporting brackets 212a and 212b. Each of the shaft supporting brackets 212a and 212b has a hole (214a and 214b, respectively) therethrough adapted to receive and rotatably support the axle shaft members 14a and 14b (only one axle shaft member is shown in Fig. 20) in a spaced relationship with respect to the body 208 of the support beam member 202.

Therefore, the axle assembly in accordance with the first invention represents a novel

arrangement of the rigid drive axle assembly including the support beam member having the substantially flat central section and two opposite arm sections axially outwardly extending from said central section, the differential carrier unit secured to said flat central section of the support beam member, and two opposite axle shaft members outwardly extending from the differential carrier unit and rotatably supported by the arm sections in a spaced relationship with respect to the central section of the support beam member. The present invention provides a number of advantages over the currently employed Salisbury and Banjo style axles:

- improved strength to weight ratio;
- ease of manufacturing and reduced manufacturing cost due to the use of simple metal stampings to produce the support beam member and the front and rear covers;
- ease of assembly/disassembly and servicing of the axle assembly;
- improved modularity and commonality of axle components.

Figs. 21-28 depict a vehicular independent drive axle assembly 601 in accordance with the preferred embodiment of the second invention. To simplify the description, all elements of the second invention similar to those of the first invention are designated by numerals 600 higher.

It will be appreciated that the independent drive axle assembly 601 of the second invention may be used for both front and rear axle applications. The independent drive axle assembly 601 comprises a substantially rigid support plate member 602, a differential carrier unit 620 fastened to the support plate member 602, and two opposite stub shaft members 614a and 614b outwardly extending from the differential carrier unit 620. The vehicular

independent drive axle assembly 601 is adapted to be mounted to a sprung mass (not shown) of the motor vehicle, such as a frame or a vehicle underbody.

The support plate member 602, illustrated in detail in Figs. 26 and 27, has a substantially flat central section 604 and at least one mounting member provided for mounting the support plate member 602 to the sprung mass of the motor vehicle. Preferably, the support plate member 602 has two opposite, substantially U-shaped mounting members 606a and 606b outwardly extending from the central section 604. The mounting members 606a and 606b are provided for elastically mounting the support plate member 602 to the sprung mass of the motor vehicle through appropriate elastic members, such as elastic bushings 612a and 612b. Through openings 11a and 11b in the elastic bushings 612a and 612b, respectively, (as shown in Fig. 22) define axle attachment points to the vehicle sprung mass. Those of ordinary skill in the art will appreciate that any appropriate number of the mounting members, such as, one, three, four, etc., would be within the scope of the present invention. The flat central section 604 of the support plate member 602 defines a support plane extending substantially vertically with respect to the driving direction F of the motor vehicle.

Preferably, as illustrated in this embodiment, the support plate member 602 is a single-piece part manufactured from high strength steel by a metal deforming. It will be appreciated by those skilled in the art that alternatively any appropriate metal or non-metal material or method of manufacturing may be utilized for producing the support plate member 602 of the present invention.

The differential carrier unit 620 of the second invention is substantially identical to the differential carrier unit 20 of the first invention. The differential carrier unit 620 is fastened to

the central section 604 of the support plate member 602, and the two opposite stub shaft members 614a and 614b outwardly extend from the differential carrier unit 620 so that the stub shaft members 614a and 614b are spaced from the central section 604 of the support plate member 602 in the driving direction F of the vehicle. Distal ends of the axle stub members 614a and 614b are provided with flange members 615a and 615b, respectively, adapted for mounting corresponding axle shafts (not shown), preferably via universal joints.

As illustrated in detail in Figs. 24 and 25, the differential carrier unit 620 includes a carrier frame member 622 fastened to the central section 604 of the support plate member 602, and provided for rotatably supporting a differential case 634 and a drive pinion 638. The differential case 634 houses a conventional differential gear mechanism, well known to those skilled in the art. The drive pinion 638 has a pinion gear 638a in continuous meshing engagement with a ring gear 636, and a pinion shaft 638b operatively coupled to a vehicular drive shaft (not shown) driven by a vehicular powerplant (not shown), such as an internal combustion engine, through an input yoke 639. Alternatively, a mounting sleeve (not shown) may be used instead of the input yoke 639. The ring gear 636 is conventionally secured to the differential case 634 in any appropriate manner well known in the art.

The carrier frame member 622, illustrated in detail in Fig. 29, is, preferably, a single-piece metal part manufactured by casting, such as ductile iron casting. It will be appreciated by those skilled in the art that any appropriate metal or non-metal material or method of manufacturing may be utilized for producing the carrier frame member 622 of the present invention, such as aluminum casting, steel stamping, forging, etc. The carrier frame member 622 has a generally Y-shaped configuration and includes a neck portion 624 and two opposite,

axially spaced, coaxial bearing hub portions 626a and 626b attached to the neck portion 624 through respective leg portions 628a and 628b. The neck portion 624 has an opening 625 therethrough adapted for receiving and rotatably supporting the drive pinion 638 through an appropriate anti-friction bearing (not shown), preferably a roller bearing. The bearing hub portions 26a and 26b are provided with respective openings 627a and 627b therethrough adapted for receiving appropriate anti-friction bearings 635a and 635b for rotatably supporting the differential case 634. Preferably, the anti-friction bearings 635a and 635b are tapered roller bearings. Moreover, the bearing hub portions 626a and 626b are provided with mounting flange portions 630a and 630b respectively, for fastening the carrier frame member 622 to the flat central section 604 of the support plate member 602 so that the neck portion 624 extends through an opening 608 in the flat central section 604 of the support plate member 602. Preferably, each of the mounting flange portions 630a and 630b has two mounting holes 631a and 631b, respectively, adapted to receive bolts 621 (shown in Figs. 24 and 25). In an assembled condition of the drive axle assembly 601, the bolts 621 extend through the mounting holes 631a and 631b in the carrier frame member 622 and bolt holes formed in the central section 604 of the support plate member 602 to extend therethrough, thus fastening the carrier frame member 622 to the central section 604 of the plate member 602. The substantially flat, central section 604 of the support plate member 602 is further provided with a central opening 608 therethrough adapted for receiving the carrier frame member 622 of the differential carrier unit 620, as illustrated in Figs. 23-27.

Therefore, the differential carrier unit 620 of the present invention is a self-contained unit wherein the carrier frame member 622 supports all the significant elements of the

differential carrier unit and a final drive, such as the differential case 634 housing the differential gear mechanism, differential bearings 635a and 635b, threaded differential adjusters 632a and 632b, differential adjuster locks, oil seals, the drive pinion 638, drive pinion bearings, and the input yoke 639. Preferably, the carrier frame member 622 fastened to the central section 604 of the support plate member 602 using conventional fasteners, such as bolts 621. The carrier frame member 622 of the present invention improves the modularity of design of the differential carrier unit, substantially simplifies the assembly and servicing of the differential carrier unit, and reduces the number of required machining operations.

In order to prevent the differential carrier unit 620 from contamination and provide a supply of a lubricant, the differential carrier unit 620 is enclosed into a housing formed by a rear cover 640 and a front cover 646 secured to opposite surfaces of the central section 604 of the support plate member 602 in any appropriate manner well known in the art. In accordance with the preferred embodiment of the present invention, both the rear cover 640 and the front cover 646 are manufactured by metal stamping of aluminum-killed draw quality (AKDQ) grade steel. It will be appreciated by those skilled in the art that alternatively any appropriate metal material, such as steel or aluminum, or non-metal material may be utilized. Preferably, the front cover 646 is welded to a front surface of the central section 604 of the support plate member 602, while the rear cover 640 is fastened to a rear surface of the central section 604 of the support plate member 602 using conventional threaded fasteners, such as a plurality of bolt/nut fasteners 643, as shown in Fig. 21. It will be appreciated by those skilled in the art that the rear cover 640 and the front cover 646 may be secured to the support plate member 602 by any appropriate manner well known in the art.

Moreover, the front cover 646 has a front opening 648 (shown in Fig. 26) for rotatably supporting and receiving therethrough a distal end of the pinion shaft 638b of the drive pinion 638. The rear cover 640 incorporates two opposite through holes 642 (only one is shown in Figs. 25 and 26) for receiving the axle shaft members 614a and 614b therethrough. Each of the through holes 642 is provided with a self-centering seal 644.

Furthermore, the differential carrier unit 620 is provided with a front suspension member 650 at a front portion thereof for elastically mounting the front portion of the differential carrier unit 620 of the axle assembly 1 to the vehicle sprung mass through an appropriate elastic member, such as an elastic bushing 656. In accordance with the preferred embodiment of the present invention, as illustrated in detail in Fig. 26, the front suspension member 650 includes a suspension arm 652 extending from a mounting flange 654 attached to the front cover 646. The elastic bushing 656 is secured at a distal end of the suspension arm 652. A through opening 657 in the elastic bushing 656 (shown in Fig. 22) defines a front axle attachment point to the vehicle sprung mass.

Therefore, the independent drive axle assembly in accordance with the second invention represents a novel arrangement of the drive axle assembly including the support plate member having the substantially flat central section and two opposite mounting arm sections laterally outwardly extending from the central section, the differential carrier unit secured to the flat central section of the support plate member, and two opposite stub shaft members outwardly extending from the differential carrier unit and rotatably supported by the differential carrier unit in a spaced relationship with respect to the central section of the support plate member. The present invention provides a number of advantages over the

currently employed independent drive axle assemblies:

- improved strength to weight ratio;
- ease of manufacturing and reduced manufacturing cost due to the use of simple metal stampings to produce the support plate member and the front and rear covers;
- ability to change attachment points without affecting a structure of the differential carrier unit;
- ease of assembly/disassembly and servicing of the axle assembly;
- improved modularity and commonality of axle components.

The foregoing description of the preferred embodiments of the present invention has been presented for the purpose of illustration in accordance with the provisions of the Patent Statutes. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiments disclosed hereinabove were chosen in order to best illustrate the principles of the present invention and its practical application to thereby enable those of ordinary skill in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated, as long as the principles described herein are followed. Thus, changes can be made in the above-described invention without departing from the intent and scope thereof. It is also intended that the scope of the present invention be defined by the claims appended thereto.

What is claimed is:

1. An axle assembly for a motor vehicle comprising:

a support beam member having a substantially flat central section and two opposite arm sections oppositely extending from said central section;

a differential carrier unit secured to said flat central section of said support beam member; and

two opposite axle shaft members oppositely extending from said differential carrier unit and rotatably supported on said arm sections, said axle shaft members being spaced from said flat central section of said support beam member with respect to a driving direction of said motor vehicle.

2. The axle assembly as defined in claim 1, wherein said flat central section of said support beam member defines a support plane that is substantially orthogonal to said driving direction of said motor vehicle.

3. The axle assembly as defined in claim 1, wherein each of said arm sections of said support beam member has tubular shape.

4. The axle assembly as defined in claim 3, wherein each of said arm sections of said support beam member is substantially rectangular in cross-section.

5. The axle assembly as defined in claim 3, wherein each of said arm sections of said support beam member is substantially circular in cross-section.

6. The axle assembly as defined in claim 1, wherein said central section of said support beam member has a substantially C-channel cross-section.

7. The axle assembly as defined in claim 1, wherein said two arm sections are formed integrally with said central section.

8. The axle assembly as defined in claim 1, wherein said two arm sections are formed integrally with said central section as a unitary single-piece part.

9. The axle assembly as defined in claim 1, wherein each of said arm sections of said support beam member is substantially flat and has a shaft supporting bracket provided thereon for rotatably supporting said axle shaft members.

10. The axle assembly as defined in claim 9, wherein said shaft supporting brackets are provided at a distal end of said arm sections of said support beam member.

11. The axle assembly as defined in claim 9, wherein said support beam member has a substantially I-shaped cross-section.

12. The axle assembly as defined in claim 11, wherein said I-beam cross-section of said support beam member is integrally formed by two C-shaped beams secured to each other.

13. The axle assembly as defined in claim 1, wherein said differential carrier unit includes a carrier frame member for rotatably supporting a differential case and a drive shaft.

14. The axle assembly as defined in claim 13, wherein said flat support beam member has a central opening such that said carrier frame member extends through said central opening.

15. The axle assembly as defined in claim 1, wherein said central section of said support beam member has a central opening therethrough and said differential carrier unit extends through said central opening.

16. The axle assembly as defined in claim 15, wherein said differential carrier unit includes a carrier frame member fastened to said central section of said support beam member so as to extend through said central opening, said carrier frame member is provided for rotatably supporting a differential case and a drive pinion of a final drive.

17. The axle assembly as defined in claim 16, wherein said carrier frame member has a generally Y-shaped configuration, and includes two coaxially spaced bearing hub portions for

rotatably supporting said differential case, a neck portion for rotatably supporting said drive pinion, and leg portions for coupling said neck portion to said bearing hub portions.

18. The axle assembly as defined in claim 17, wherein said carrier frame member is provided with a mounting flange portion for fastening said carrier frame member to said central section of said support beam member.

19. The axle assembly as defined in claim 18, wherein each of said bearing hub portions of said carrier frame member is provided with a mounting flange portion.

20. The axle assembly as defined in claim 17, wherein said carrier frame member is a unitary single-piece part manufactured by one of a casting or forging.

21. The axle assembly as defined in claim 1, further including a rear cover and a front cover secured to opposite surfaces of said flat central section of said support beam member for enclosing said differential carrier unit, said rear cover having two opposite through holes for receiving said axle shaft members therethrough.

22. The axle assembly as defined in claim 16, further including a rear cover and a front cover secured to opposite surfaces of said flat central section of said support beam member for enclosing said differential carrier unit.

23. The axle assembly as defined in claim 22, wherein said front cover having a front opening for rotatably supporting and receiving therethrough a pinion shaft of said drive pinion.

24. The axle assembly as defined in claim 1, wherein said central section of said support beam member is enlarged relative to said arm sections.

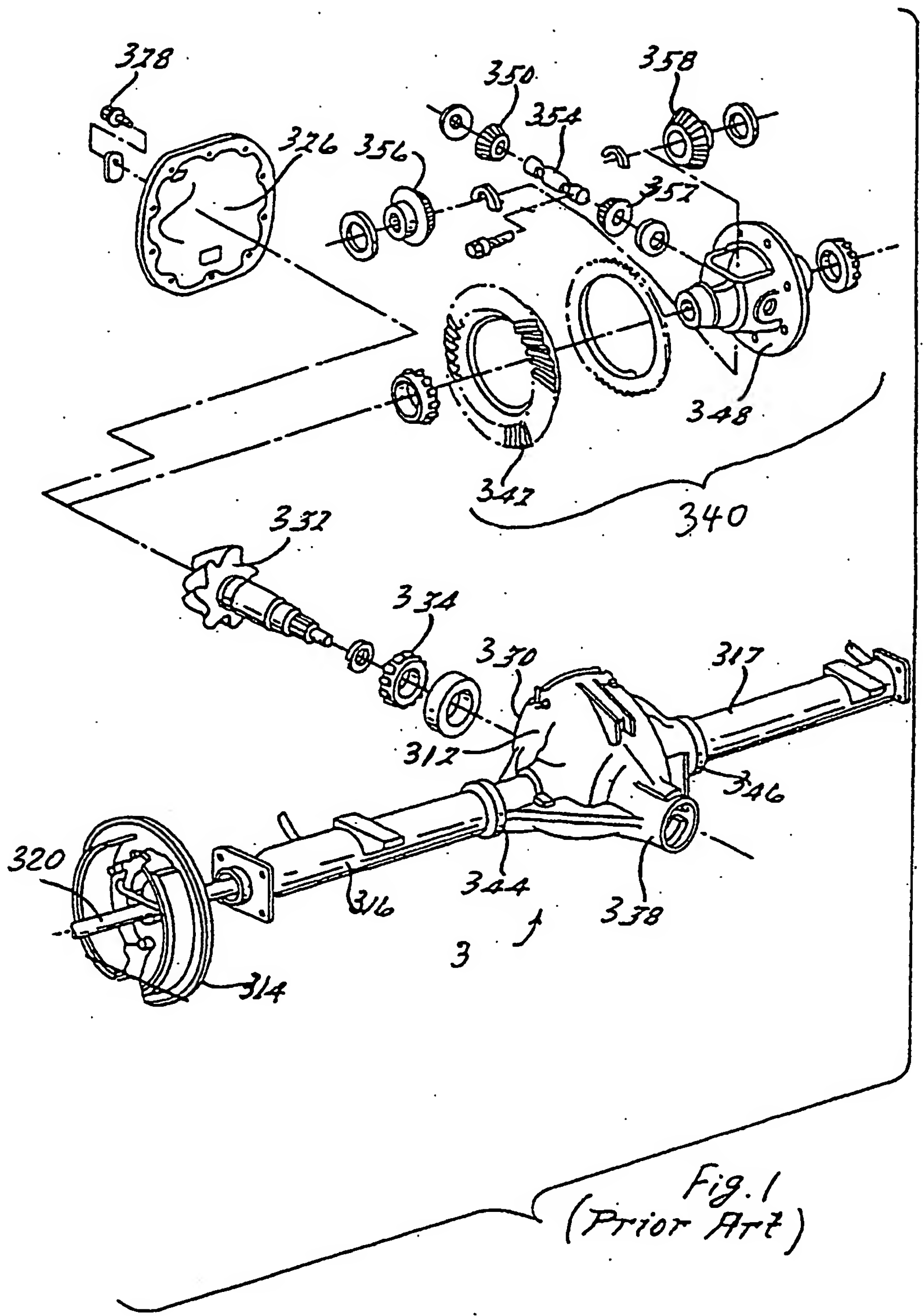


Fig. 1
(Prior Art)

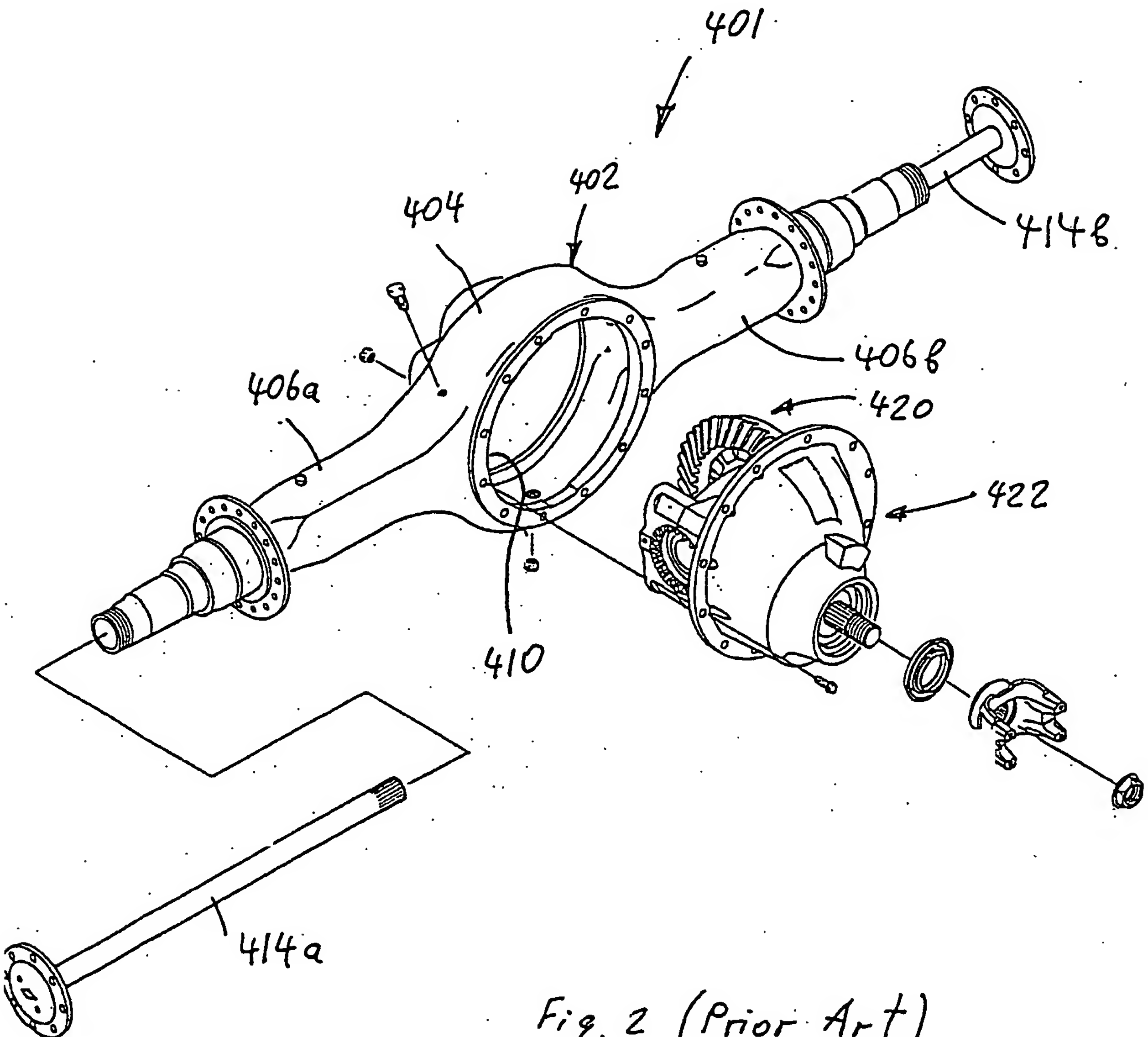


Fig. 2 (Prior Art)

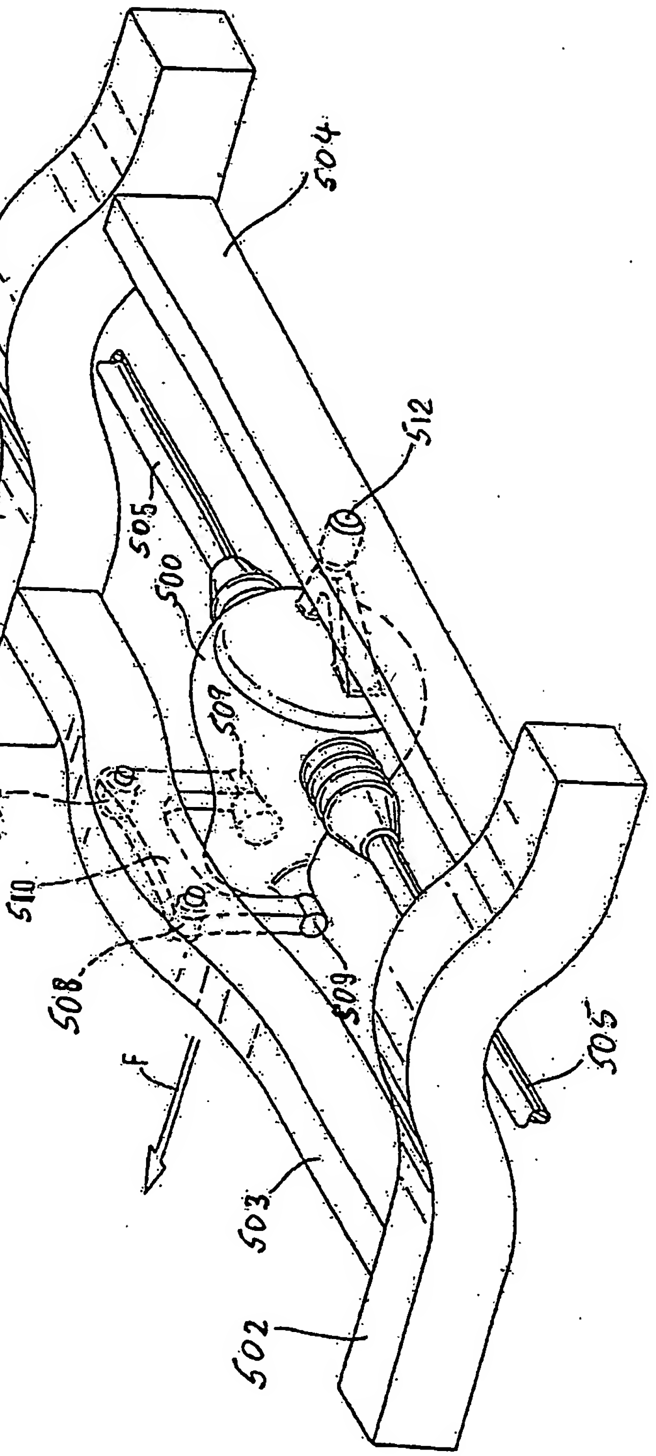


Fig. 3 (Prior Art)

Fig. 4

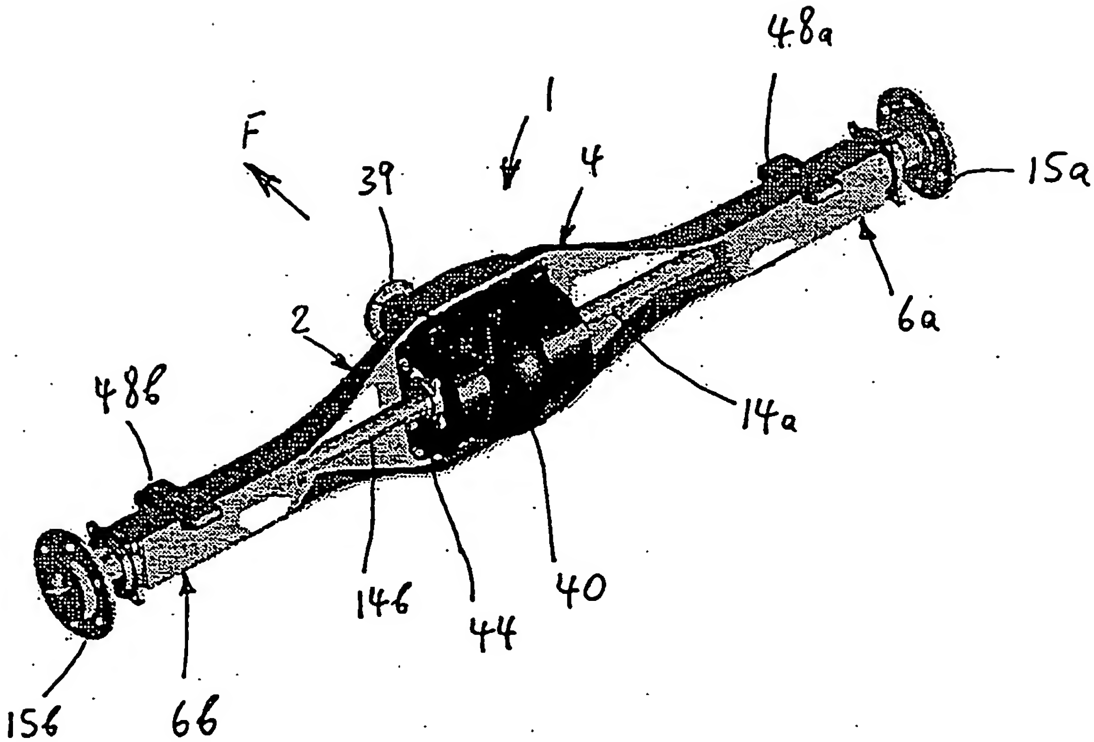
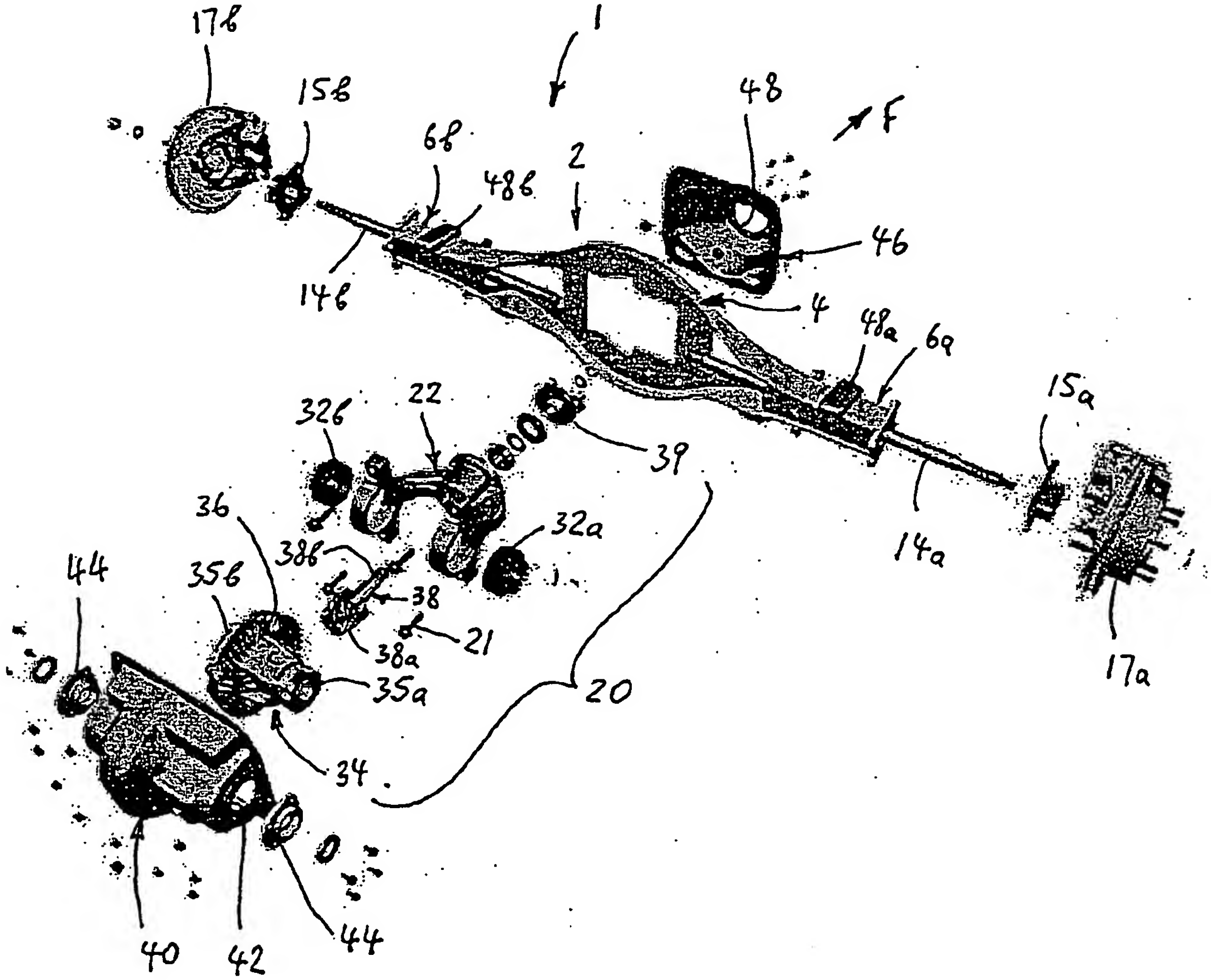


Fig. 5


1
17b
15b
6b
48b
2
48
F
46
14b
4
48a
6a
15a
32b
22
39
14a
36
32a
38b
35b
38
44
21
17a
35a
20
34
40
42
44

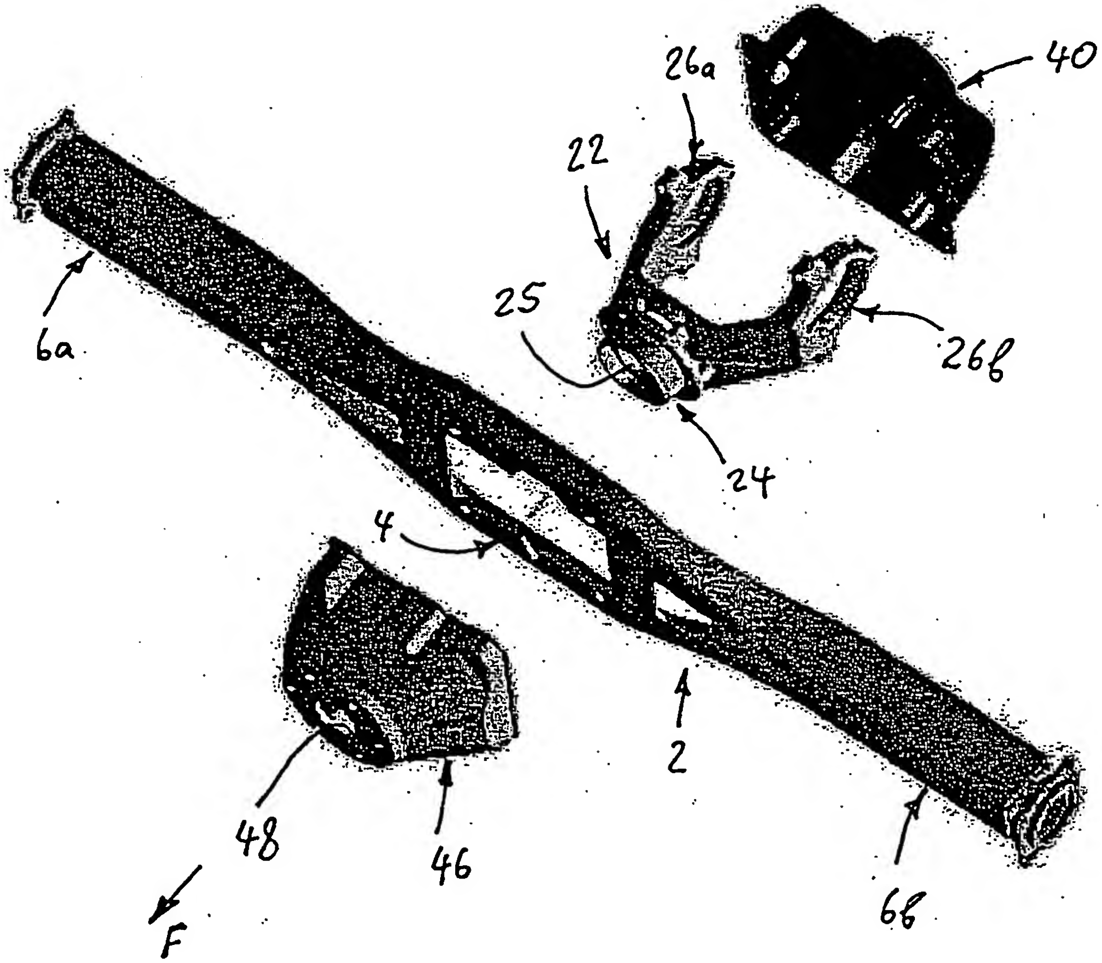


Fig. 6

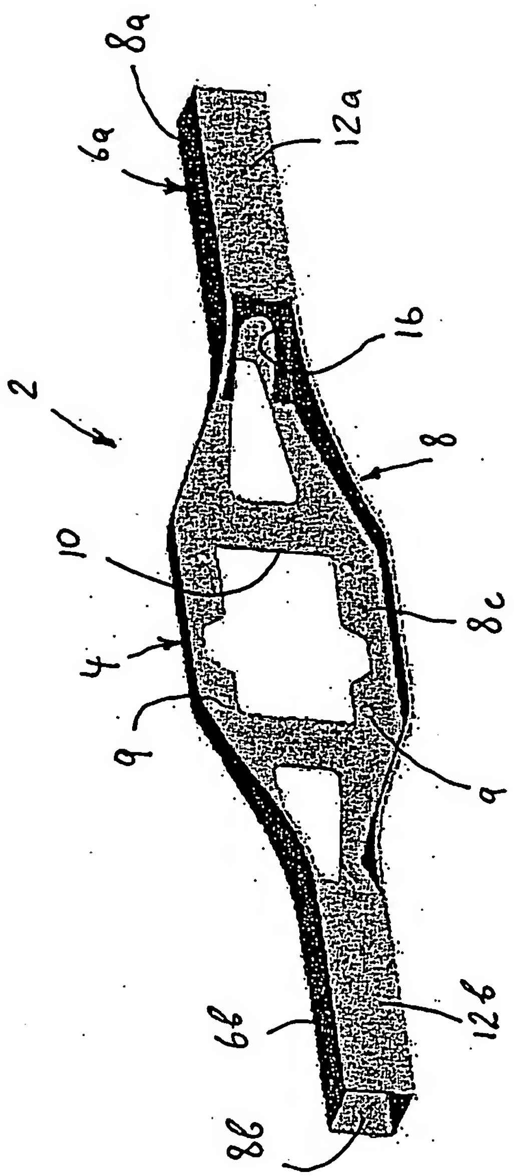


Fig. 7

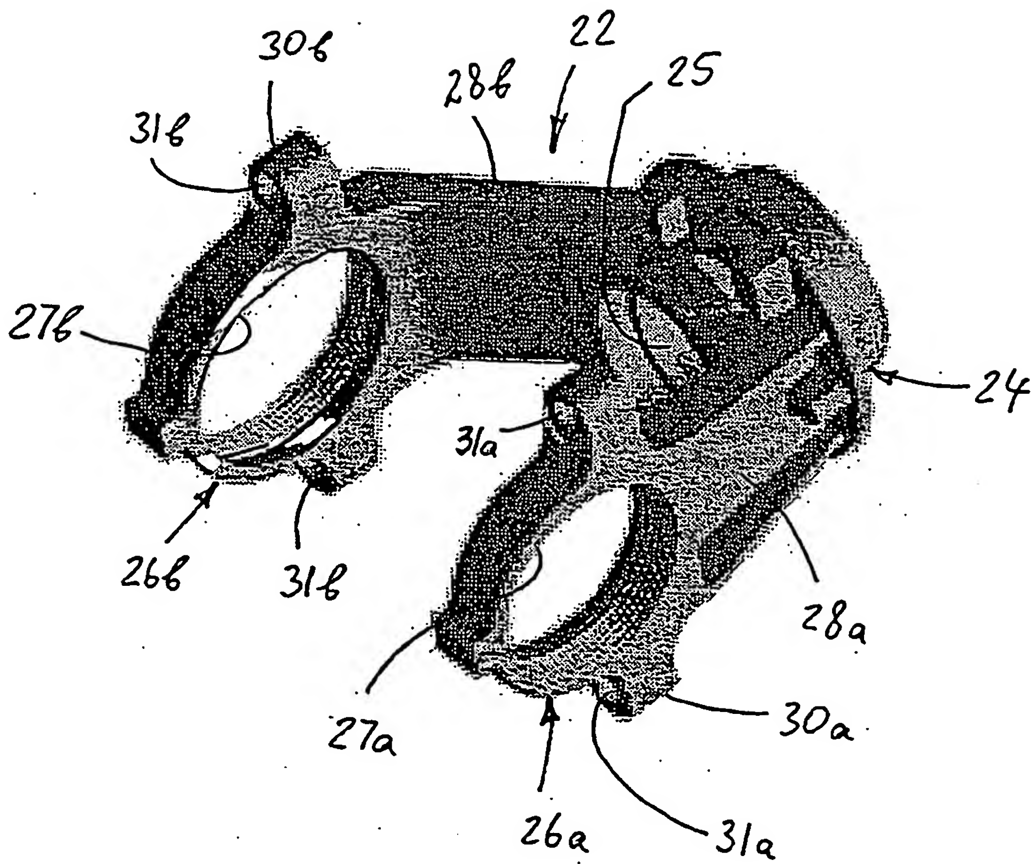


Fig. 3

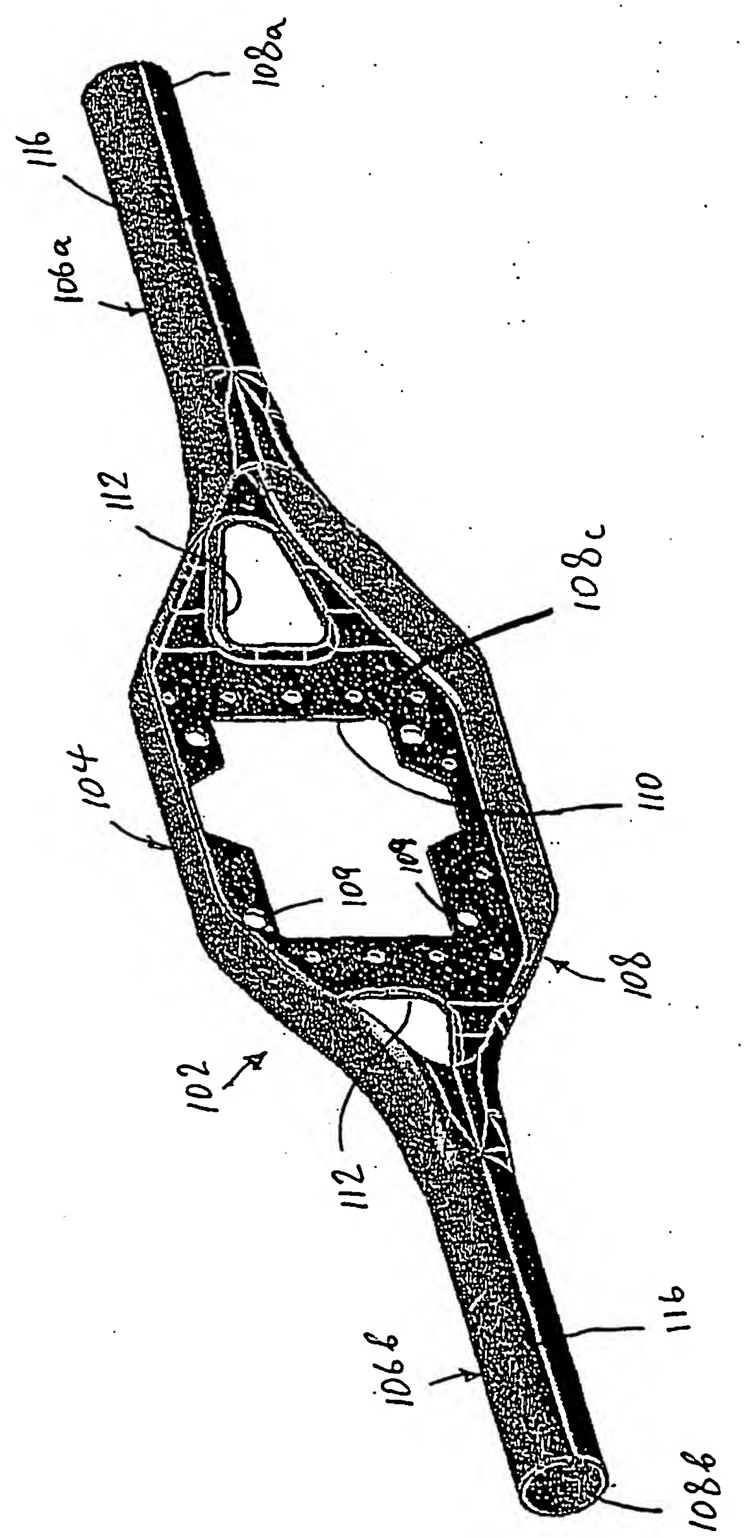

108a
116
106a
112
108c
104
110
109
109
108
102
112
116
106b
108b

Fig. 9

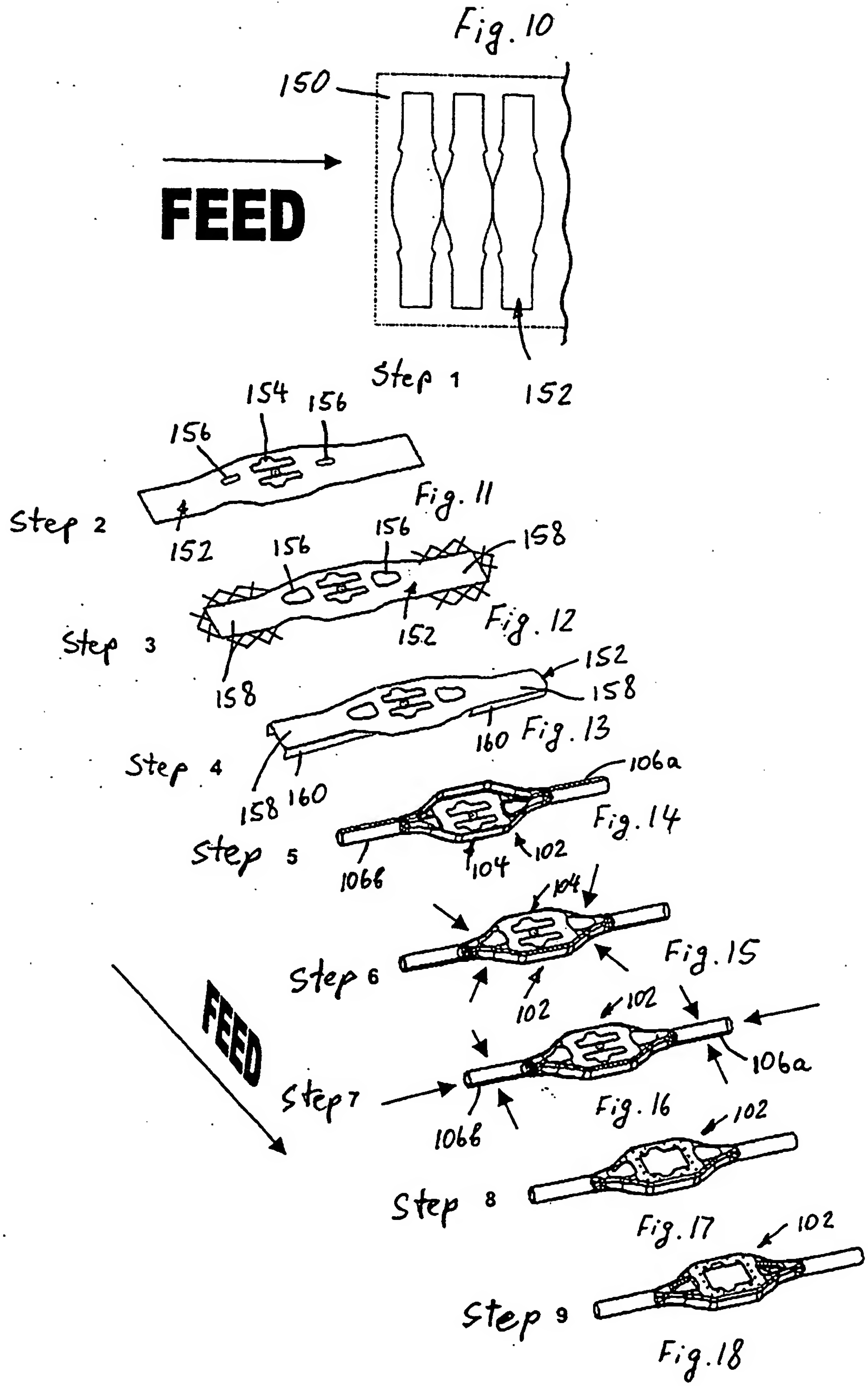


Fig. 10
150
FEED
Step 1
152
154
156
156
Step 2
152
Fig. 11
156
156
158
Step 3
152
Fig. 12
158
152
158
Step 4
160
Fig. 13
158
160
106a
Step 5
Fig. 14
106b
104
102
104
Step 6
Fig. 15
102
102
FEED
Step 7
106a
106b
Fig. 16
102
Step 8
Fig. 17
102
Step 9
Fig. 18

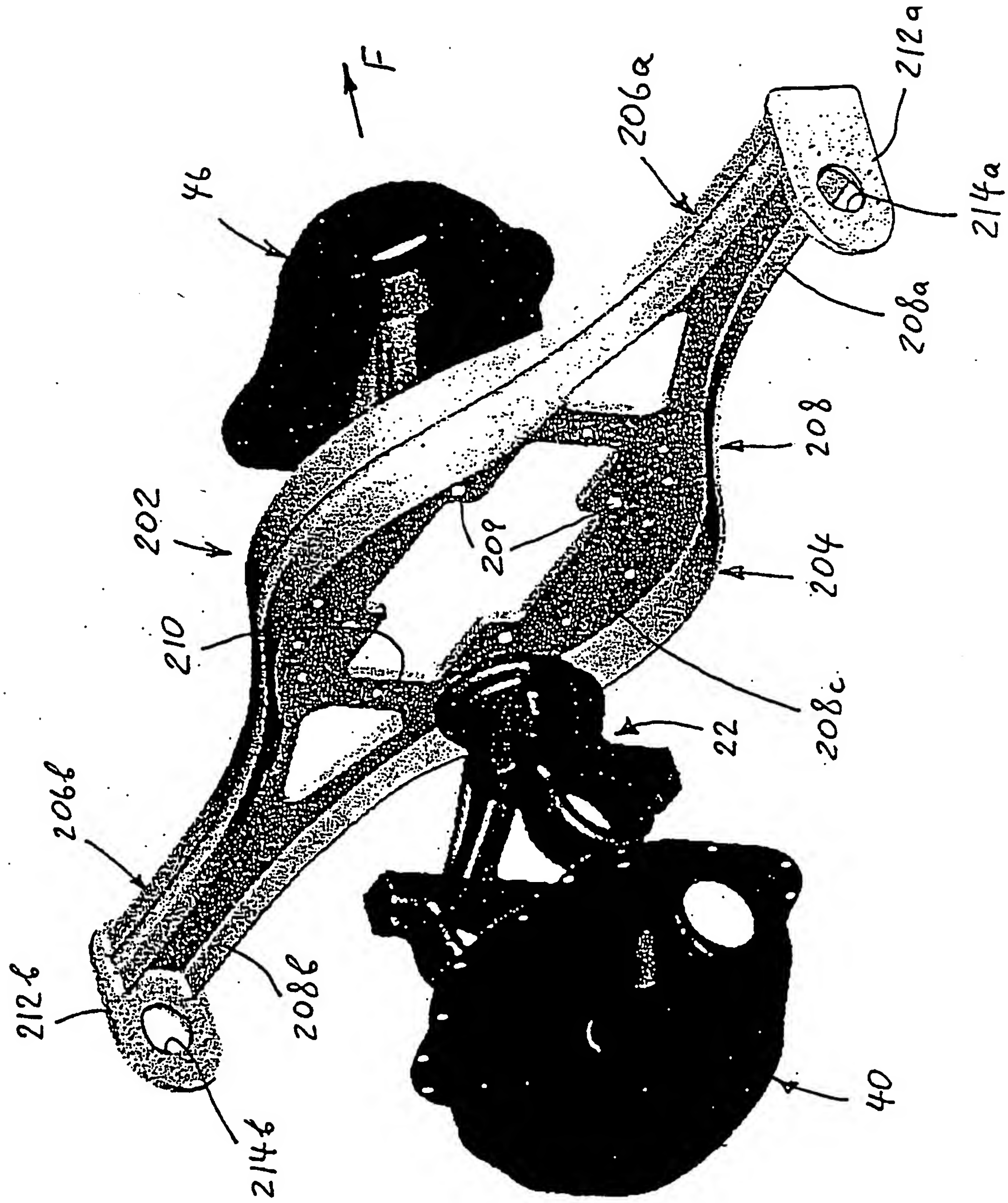

F
46
206a
212a
214a
208a
208
204
208c
22
40
202
209
210
206b
212b
208b
214b

Fig.19

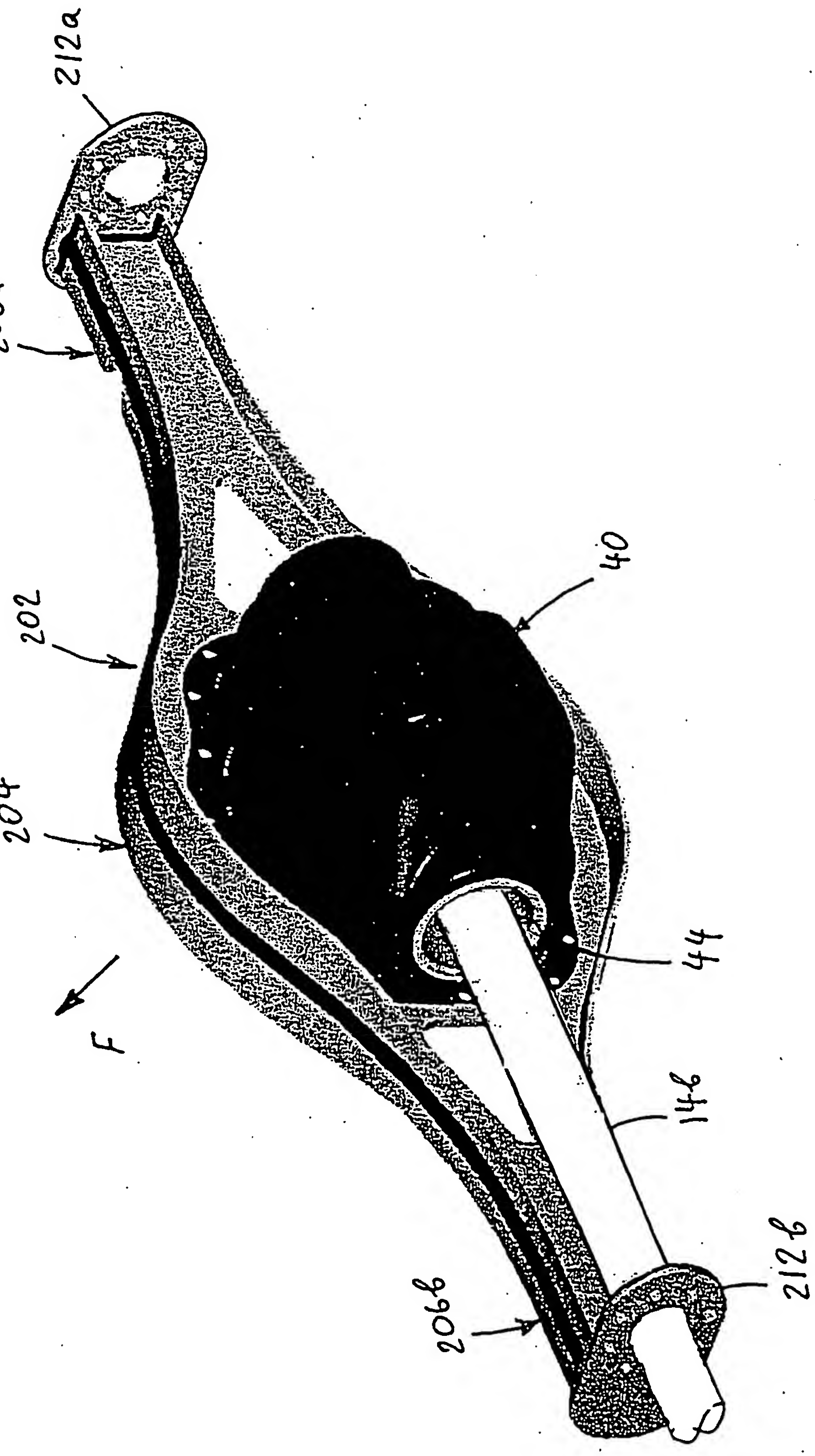


Fig. 20

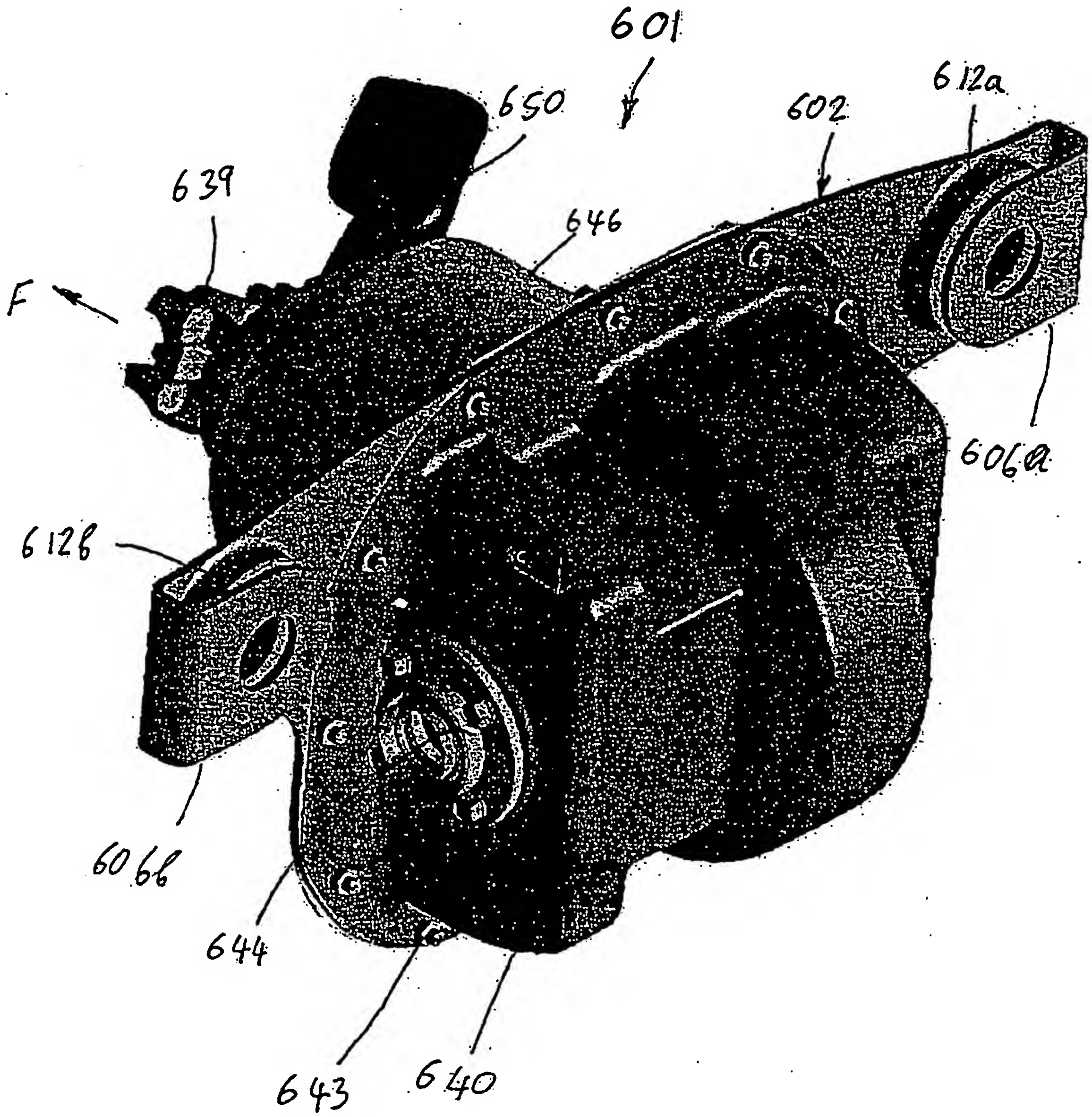


Fig.21

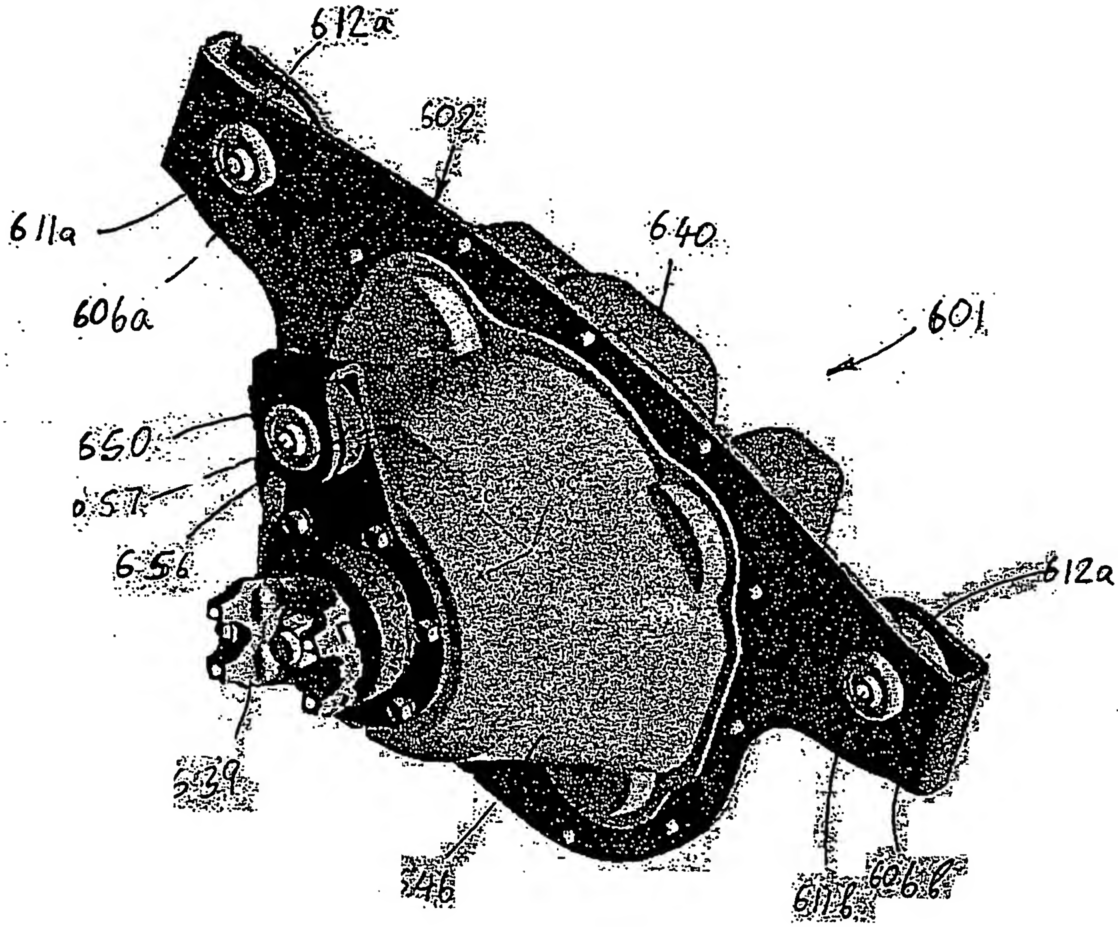


Fig. 22

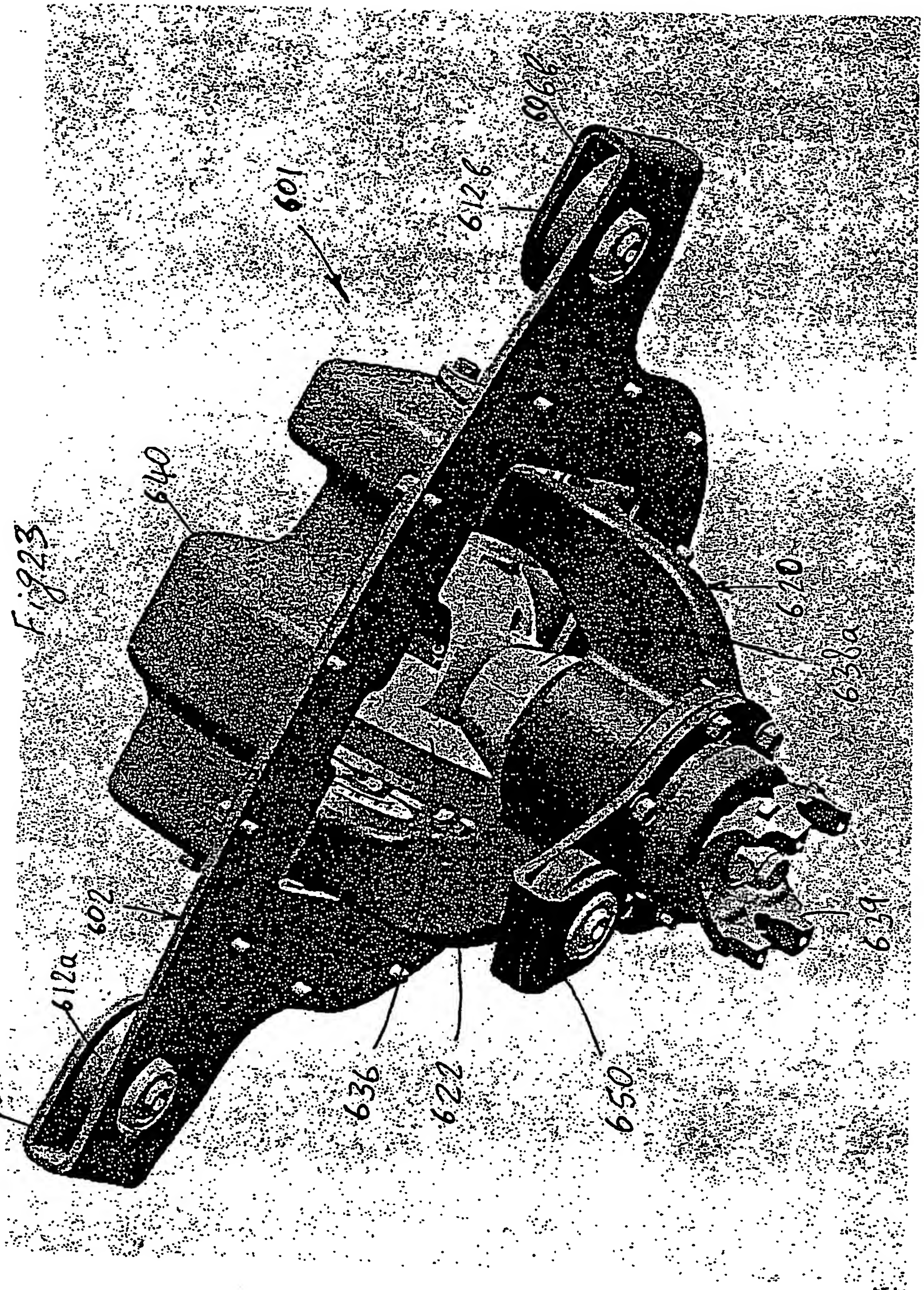


Fig. 23

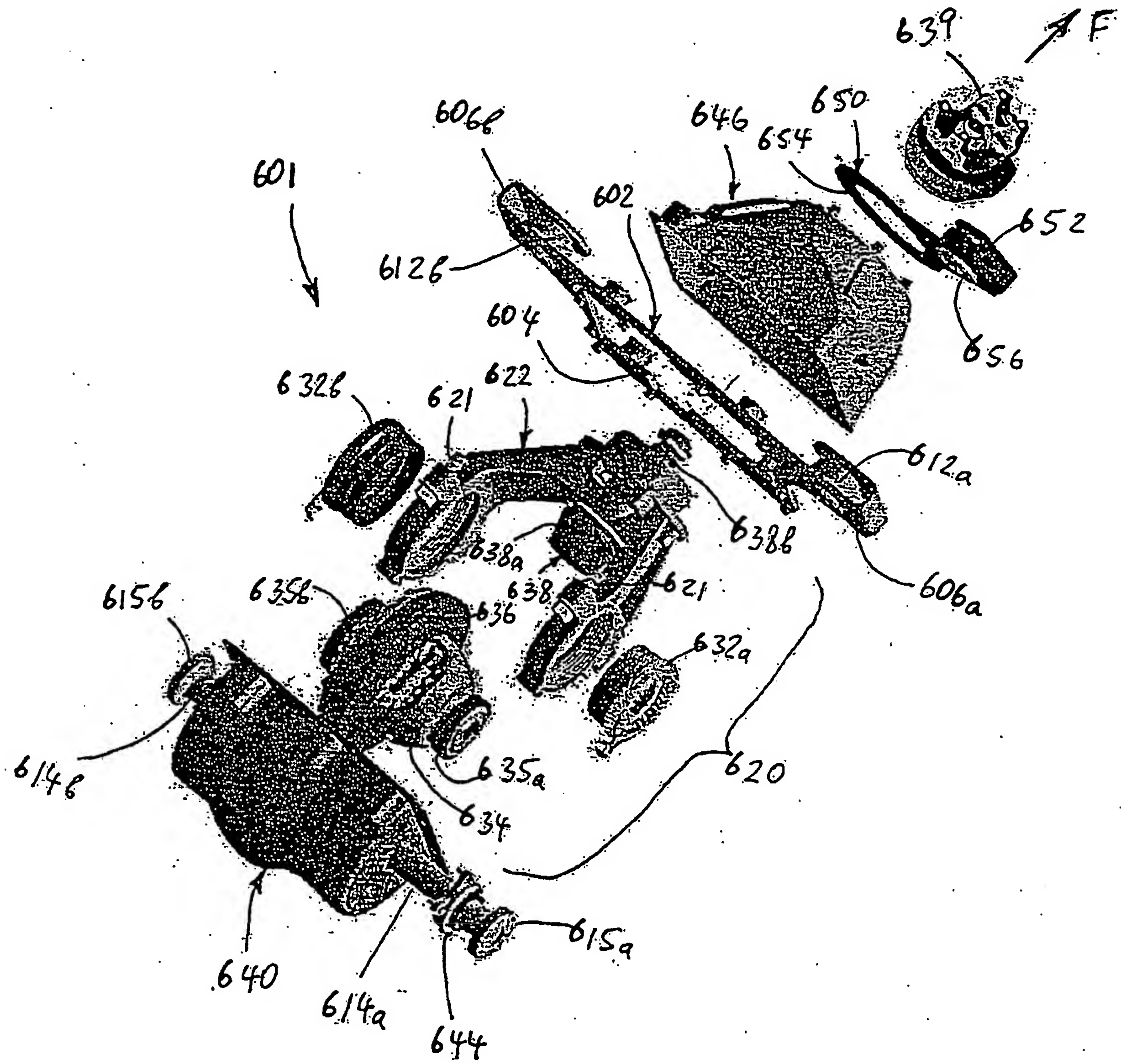

639
F
650
654
646
606b
602
601
652
612b
656
604
632b
621
622
612a
638b
638a
606a
638
621
615b
635b
636
632a
614b
635a
620
634
640
615a
614a
644

Fig.24

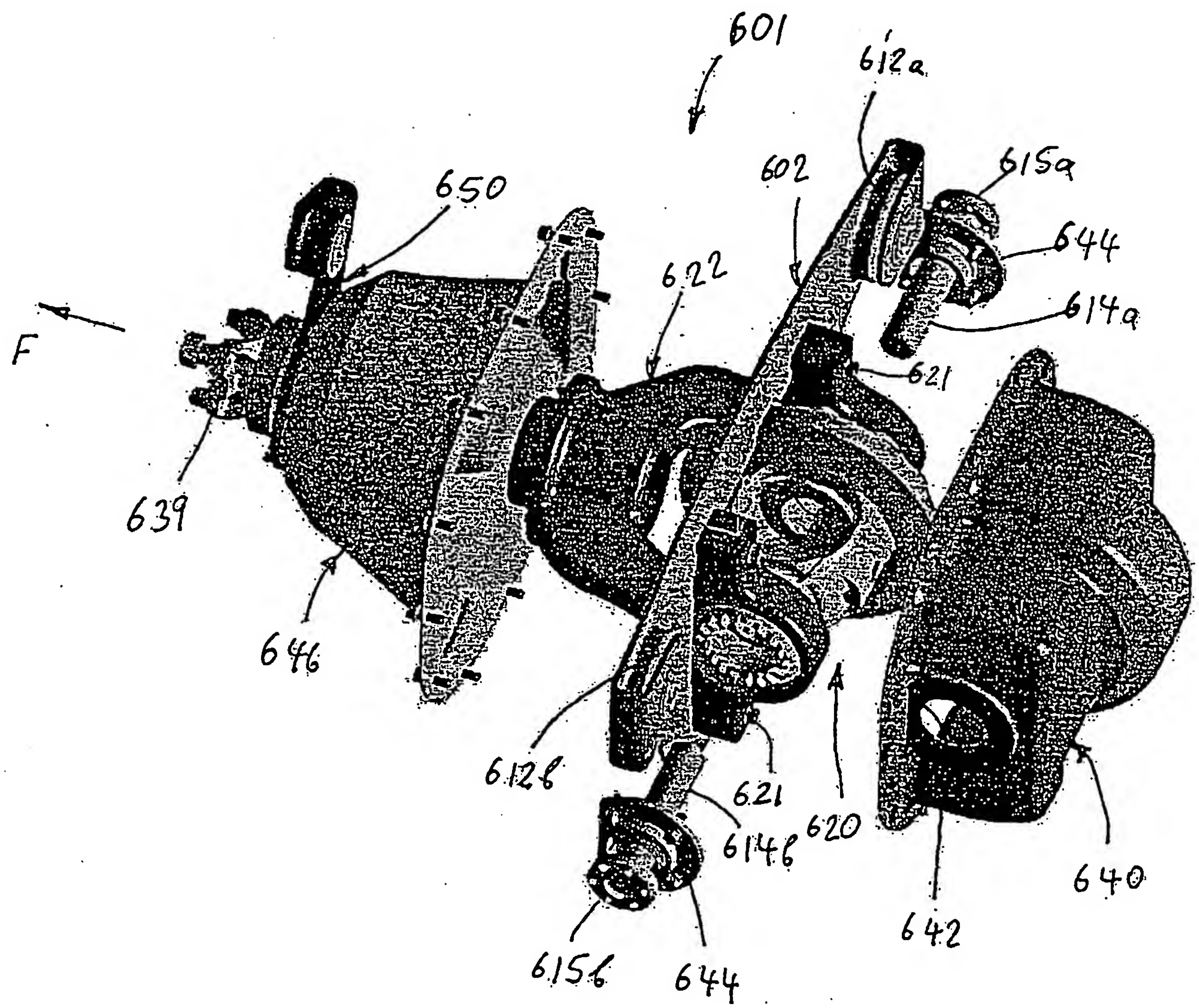

601
612a
602
615a
650
644
622
614a
F
621
639
646
612b
621
620
614b
640
642
615b
644

Fig.25

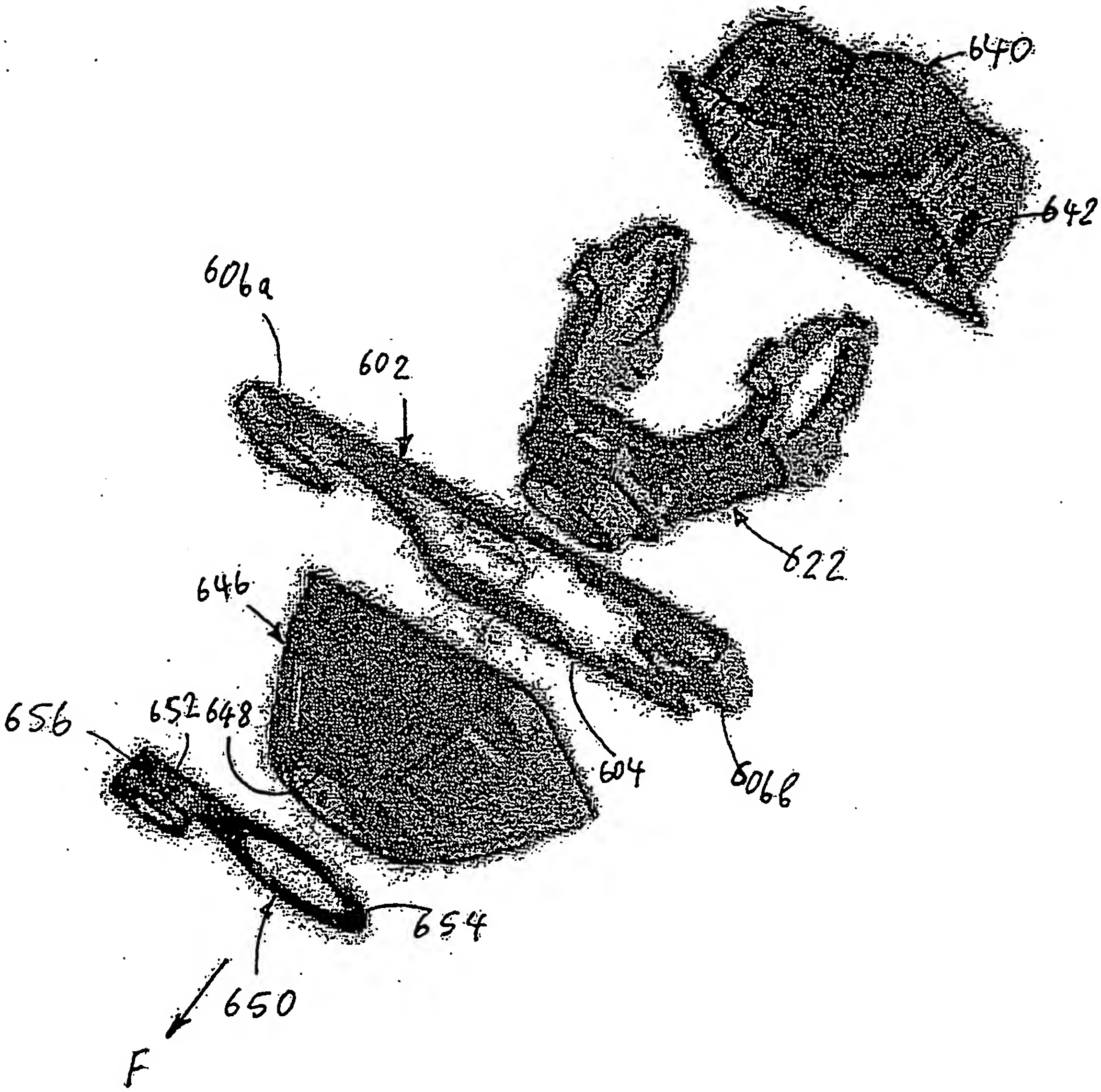


Fig.26

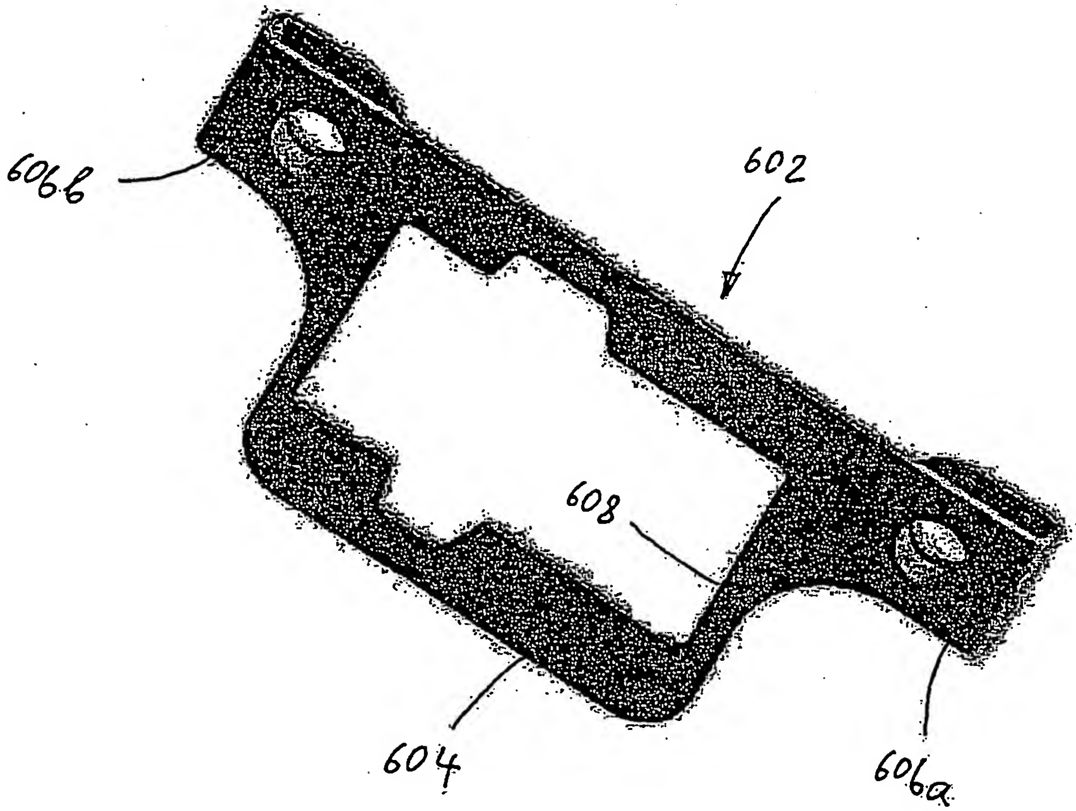


Fig.27

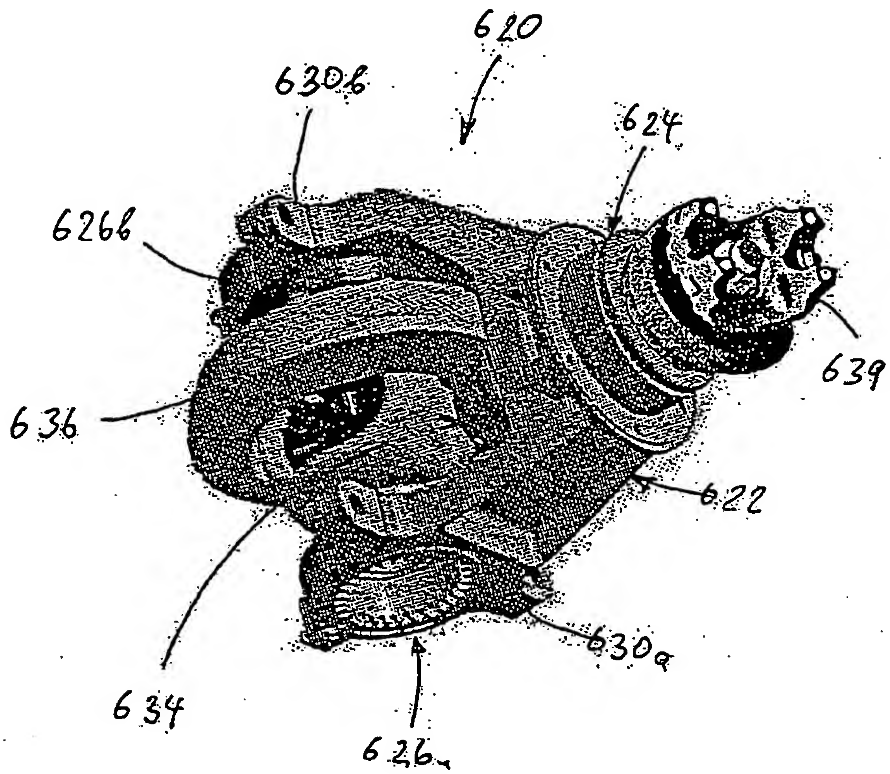


Fig.28

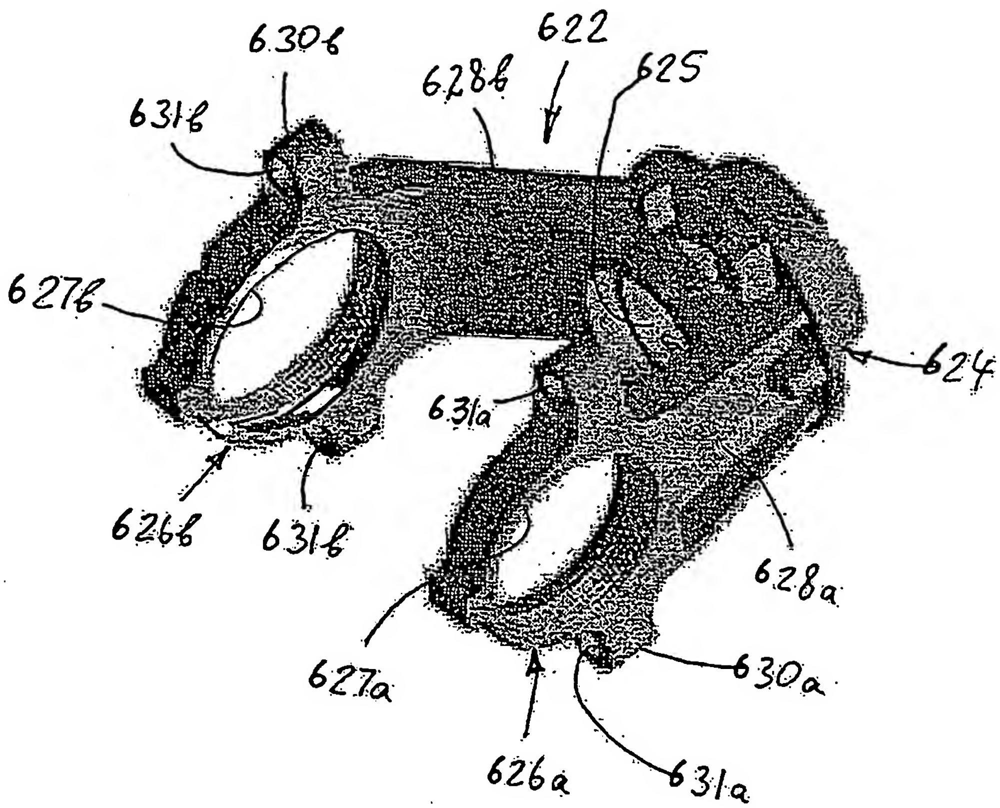

622
630b
628b
625
631b
627b
624
631a
626b
631b
628a
627a
630a
626a
631a

Fig.29

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☑ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.